Jets & Jet Substructure

US ATLAS Physics Workshop

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Overview: (this is a Workshop!)

- The following is a (completely) biased set of observations/lessons about jets and jet substructure: involving some history and some recent results (thanks especially to the BOOST2013 Working Group – Report due "SOON")
- It is meant to remind us of some relevant facts and point to rewarding future applications at the LHC
- It is neither a comprehensive history nor a thorough summary of recent contributions (my apologizes to work not mentioned)
- Jet Substructure Tools:
  Groomers – remove "UN-associated" hadrons from jet
  Taggers – ID the "primary source" of jet, Q vs G, W, Z, H, top

Warning!

Outline

- Quick review of jet and jet substructure language
- The enemy – QCD jets
- Grooming (pruning) at ATLAS (a cautionary tale)
- Qjets and Volatility
- Grooming and Tagging versus R and pT
- Closing comments

Recombination Algorithms – focus on undoing the shower

Merge partons, particles or towers pairwise based on "closeness" defined by minimum value of k_T, *i*.e. make list of metric values

(rapidity y and azimuth ϕ, p_T transverse to beam)

$$\text{Pair } ij : k_{T,(ij)} \equiv \text{Min}\left[\left(p_{T,i}\right)^{\alpha},\left(p_{T,j}\right)^{\alpha}\right]\frac{\sqrt{\left(y_i - y_j\right)^2 + \left(\phi_i - \phi_j\right)^2}}{R} \equiv \text{Min}\left[\left(p_{T,i}\right)^{\alpha},\left(p_{T,j}\right)^{\alpha}\right]\frac{\Delta R_{ij}}{R},$$

$$\text{Single } i : k_{T,i} = \left(p_{T,i}\right)^{\alpha}$$

If $k_{T,(ij)}$ is the minimum, merge pair (add 4-vectors), replace pair with sum in list and redo list;

If $k_{T,i}$ is the minimum → *i* is a jet! (no more merging for *i*, it is isolated by *R*),

1 angular size parameter *R* *(NLO, equals Cone for D = R,* R_{sep} *= 1),* plus

α *= 1,* ordinary k_T, recombine soft stuff first

α *= 0, Cambridge/Aachen* (CA), controlled by angles only

α *= -1, Anti-*k_T, just recombine stuff around hard guys – cone-like (with seeds)

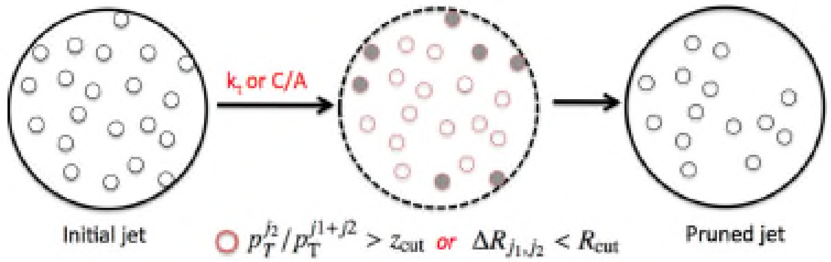
Sample Kinematic Variables -

- Mass $m_{jet}^2 = p_{jet}^{\mu} p_{jet,\mu}$
- Groomed Mass
- N-subjettiness – test for N-subjet structure, $\tau_{N,N-1}^{(\beta)} \ll 1$ if jet contains *N* subjets
- Energy Correlation Function ratios, $C_N^{(\beta)} \ll 1$ if jet contains *N* subjets

  Similar to N-subjettiness but different detailed properties !

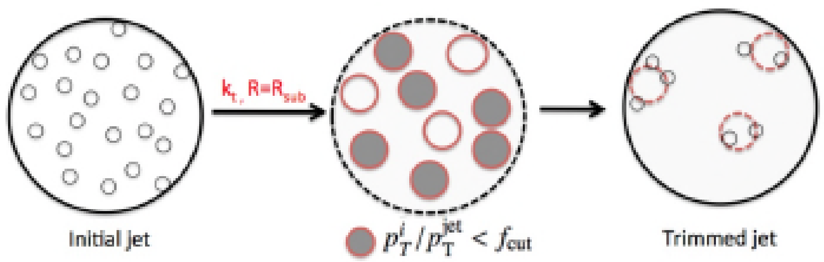
Sample Groomers – (figures from ATLAS 1306.4945)

Pruning



Based on properties at 2 $\rightarrow$ 1 mergings

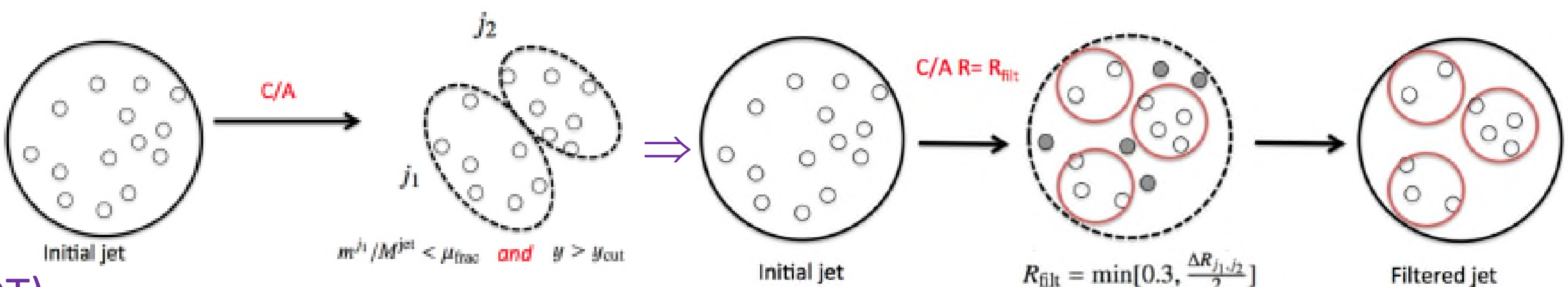
Trimming



Based on properties of subjets

Mass Drop, Filtering

Also Modified Mass Drop (mMDT)



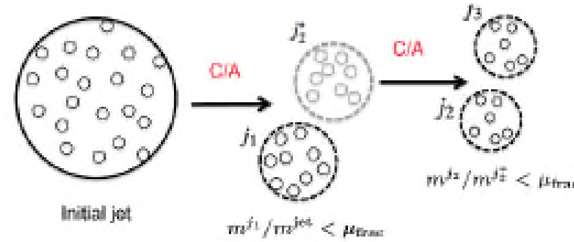
Sample Taggers -

- Simplest – Groom and cut on mass

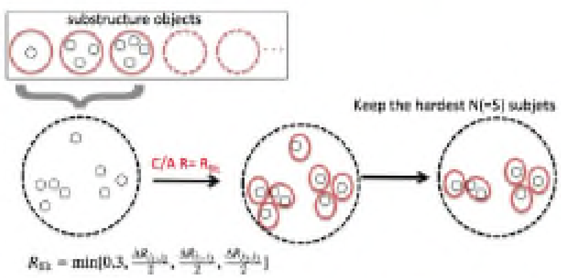
- More elaborate
  – HEP TopTagger

  look for specific number of subjets

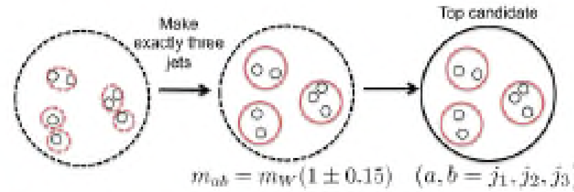
(a) Every object encountered in the declustering process is considered a 'substructure object' if it is of sufficiently low mass or has no clustering history.



(b) The mass-drop criterion is applied iteratively, following the highest subjet-mass line through the clustering history, resulting in N_i substructure objects.



(c) For every triplet-wise combination of the substructure objects found in (b), recluster the constituents into subjets and select the N_{subjet} leading-p_T subjets, with $3 \leq N_{subjet} \leq N_i$ (here, $N_{subjet} = 5$).



(d) Recluster the constituents of the N_{subjet} subjets into exactly three subjets to make the top candidate for this triplet-wise combination of substructure objects.

Comments on QCD Jets – know your enemy!

Let's define language and general properties useful in order to describe and think about QCD jets and various substructure results.

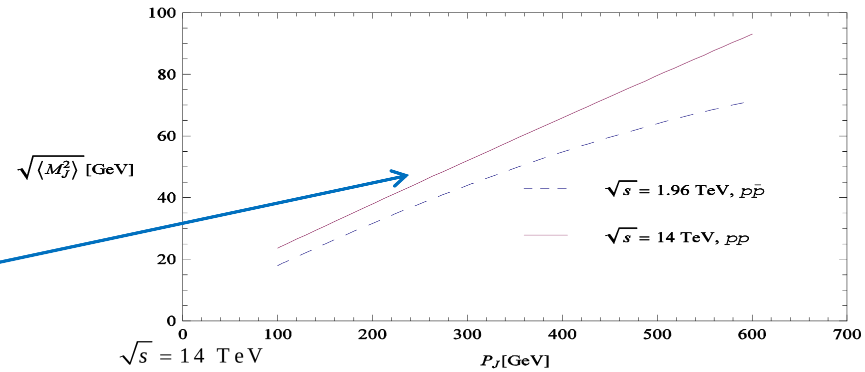
Recall History

Jets – Around for 45 Years and initially jets ≡ single partons
But partons radiate ⇒

Jet Substructure – only the last 5 years (started at BOOST 2009, where jet masses first really discussed), and we have learned a lot!

But we have (apparently) also forgotten some things!

Jet Masses in NLO QCD: A Brief Review



$\sqrt{s}$ = 14 TeV

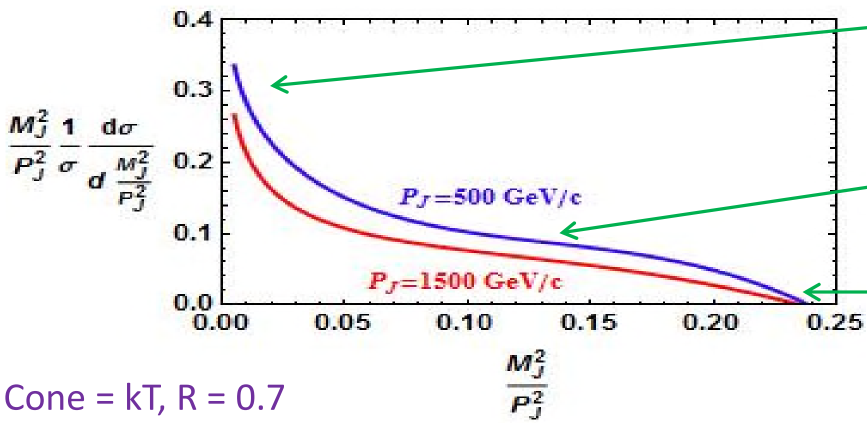
- In NLO PertThy

$$\sqrt{p_{J,\mu} p_J^{\mu}} \Rightarrow \sqrt{\langle M^2 \rangle_{NLO}} = f\left(\frac{p_J}{\sqrt{s}}\right)\sqrt{\alpha_s(p_J)}\, p_J R$$

Phase space from pdfs,
$f \sim 1$ & const

Dimensions

Jet Size, $R \sim \Delta\theta$, determined by jet algorithm



Peaked at low mass due to soft emission (log(m)/m behavior)

"Shoulder" where mass arises from hard, large angle emission

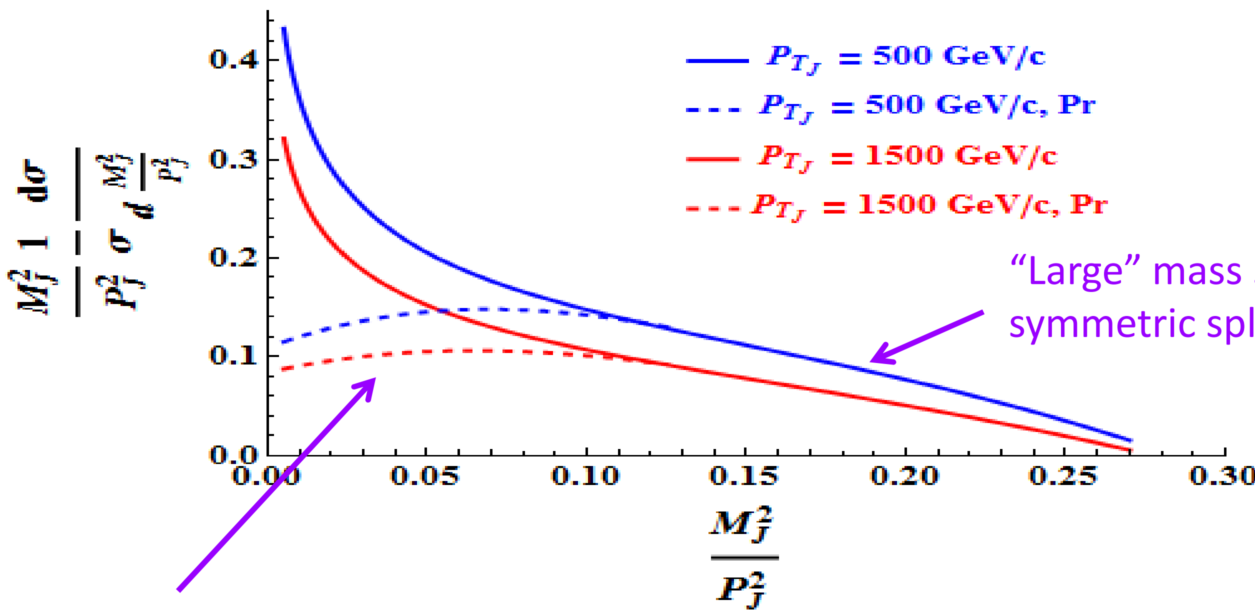
Cuts off for $(M/P)^2 > 0.25 \sim R^2/4$
(M/P > 0.5) large mass can't fit in fixed size jet,
QCD suppressed for M/P > 0.3 ($\sim \gamma < 3$)

Cone = kT, R = 0.7

Useful QCD "Rule-of-Thumb" $\Rightarrow \sqrt{\langle M^2 \rangle_{NLO}} \sim 0.2\, p_J R\, (1 \pm 0.25)$

Groomed (Pruned) Fixed Order Result (dashed):

Pruning removes, soft, wide angle constituents



"Large" mass shoulder unchanged (hard, symmetric splitting is not pruned)

Prune "small" masses to zero mass (soft, wide angle emission is pruned), only one parton remains in jet

Next add shower to all orders (radiation from colored partons)

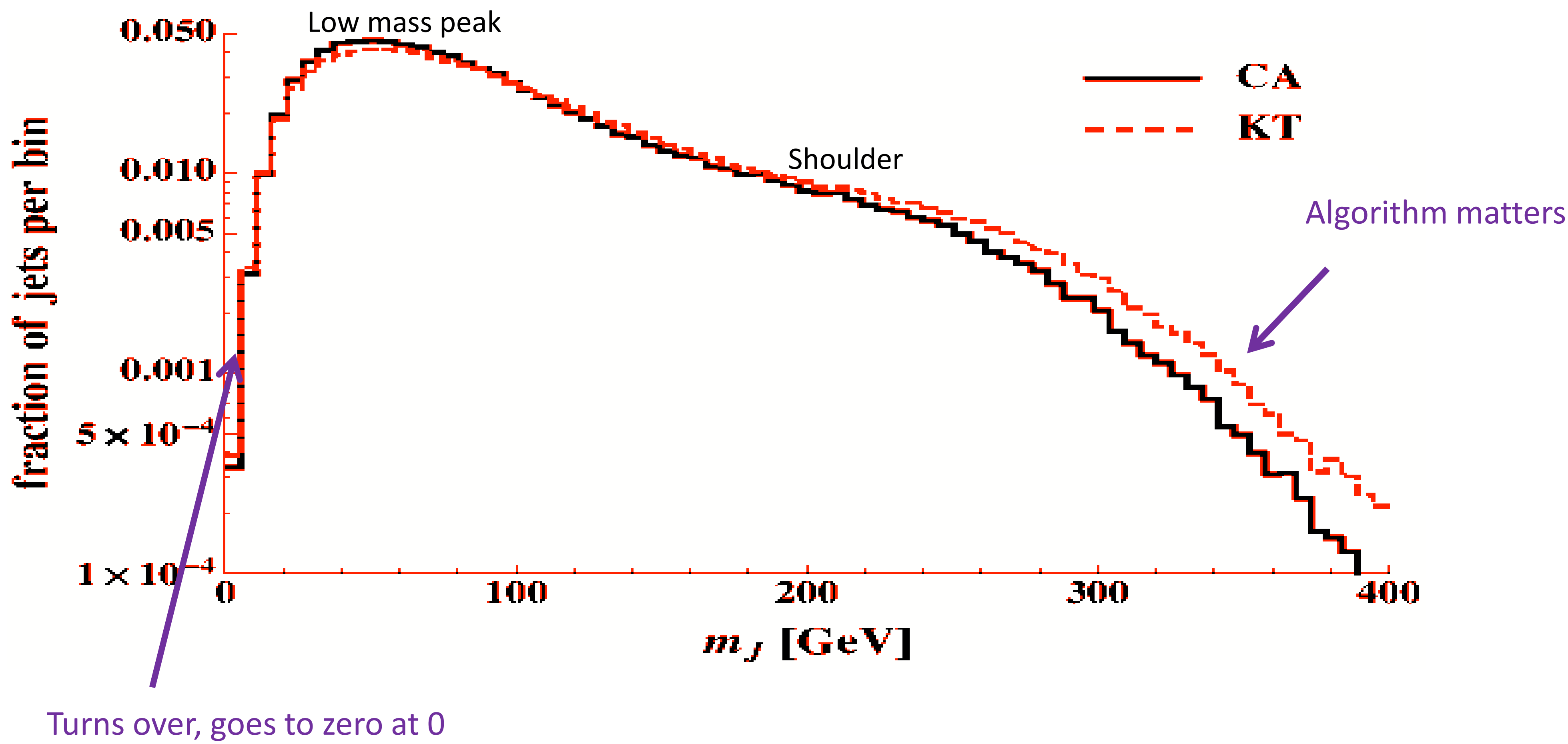
- Probability of no extra emissions and zero mass goes to zero
  (Sudakov ~ $\exp[-(\alpha_s/2\pi)C_{A/F} \ln^2(m^2/pT^2)]$).

- Low mass peak moves away from origin.

- Shoulder region only slightly changed.

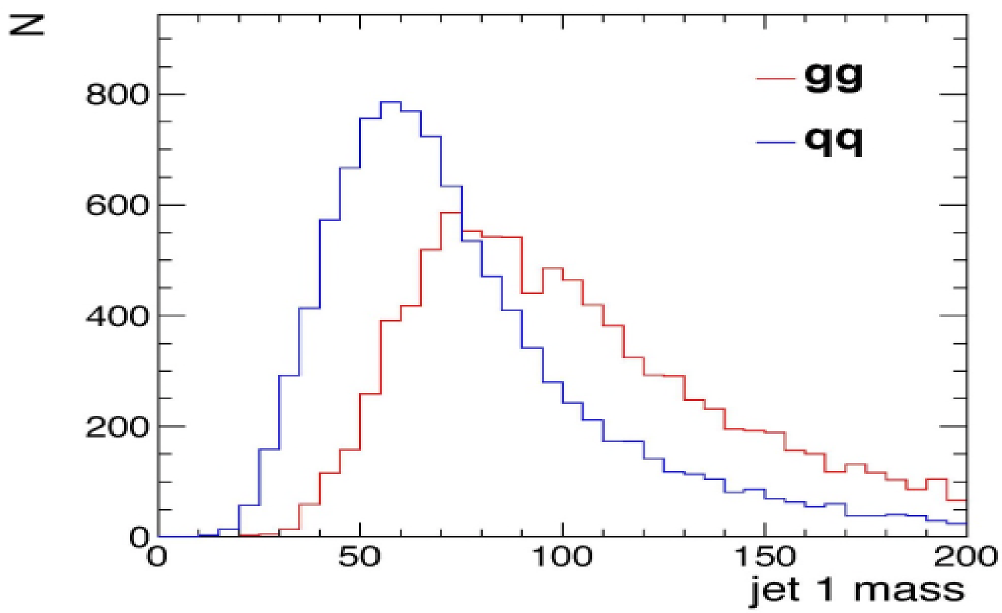
- Low mass peak order ~ 1, shoulder order α_s (factor ~ 1/10)
  – use log on y-axis to resolve both.

Jet Mass in PYTHIA (showered & matched set)
R = 1, 500 GeV/c < pT < 700 GeV/c



BOOST 2013 (Nhan Tran) results : QQ & GG samples at 8 TeV

- AkT8
- pT ~ 500 to 600 GeV



Q → G change described primarily by charge C_F (= 4/3) → C_A (= 3):

⇒ (perturbative) shoulder is higher for gluons, more "hard" radiation,

⇒ more Sudakov suppression at small masses pushes peak further from origin and to smaller value for gluons,

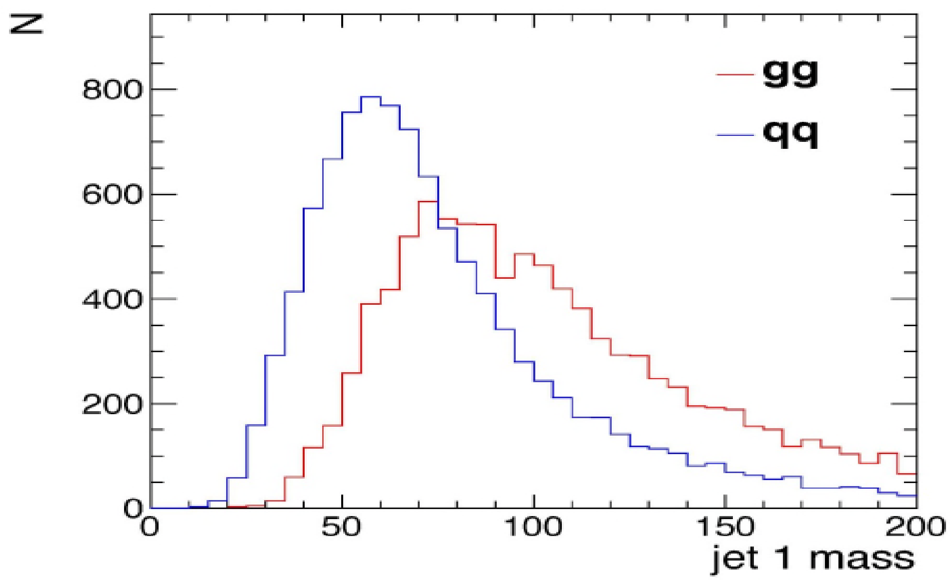
⇒ a larger fraction of gluon jets (than quark jets) are in the shoulder (small pruning) region of jet mass distribution!

⇒ gluons have larger average mass.

Leading Jet mass: Before & after grooming (pruning)

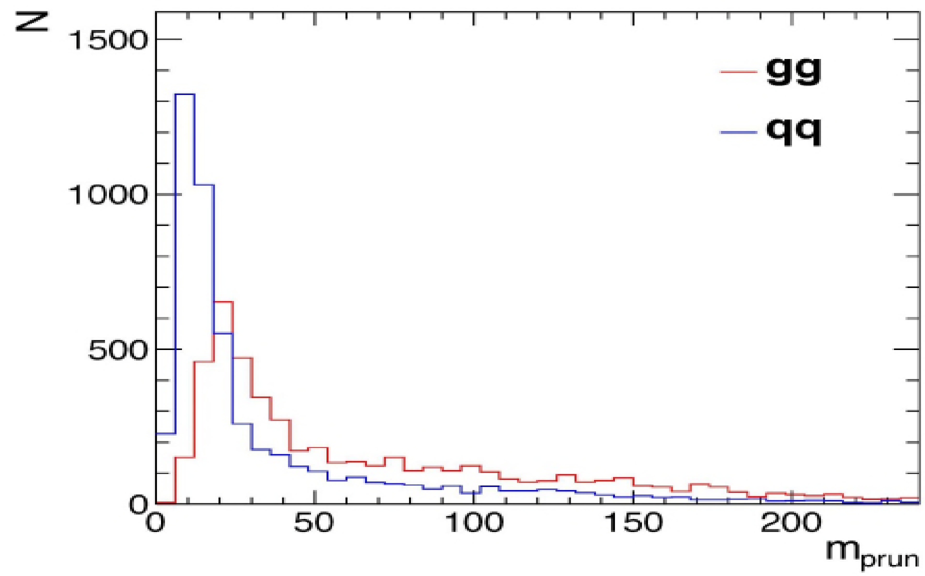
Pruning pushes low mass peak to lower mass and leaves height of shoulder largely unchanged

UNpruned



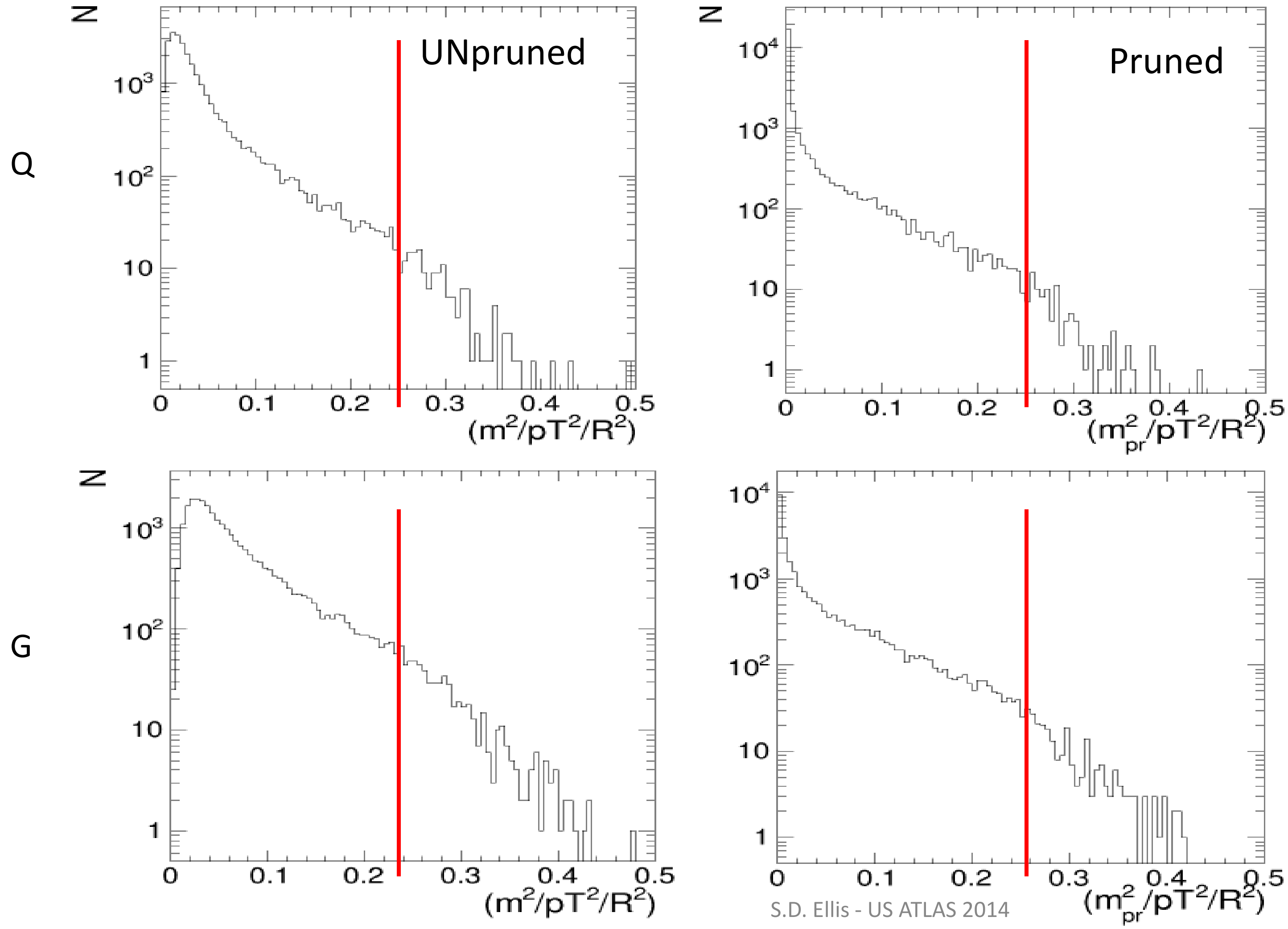
G has larger average mass

Pruned



G has higher shoulder

Jet mass distributions - Linear on x-axis, Log on y-axis (focus on large values)



Gluon jets are a bit more massive, i.e., a broader distribution;

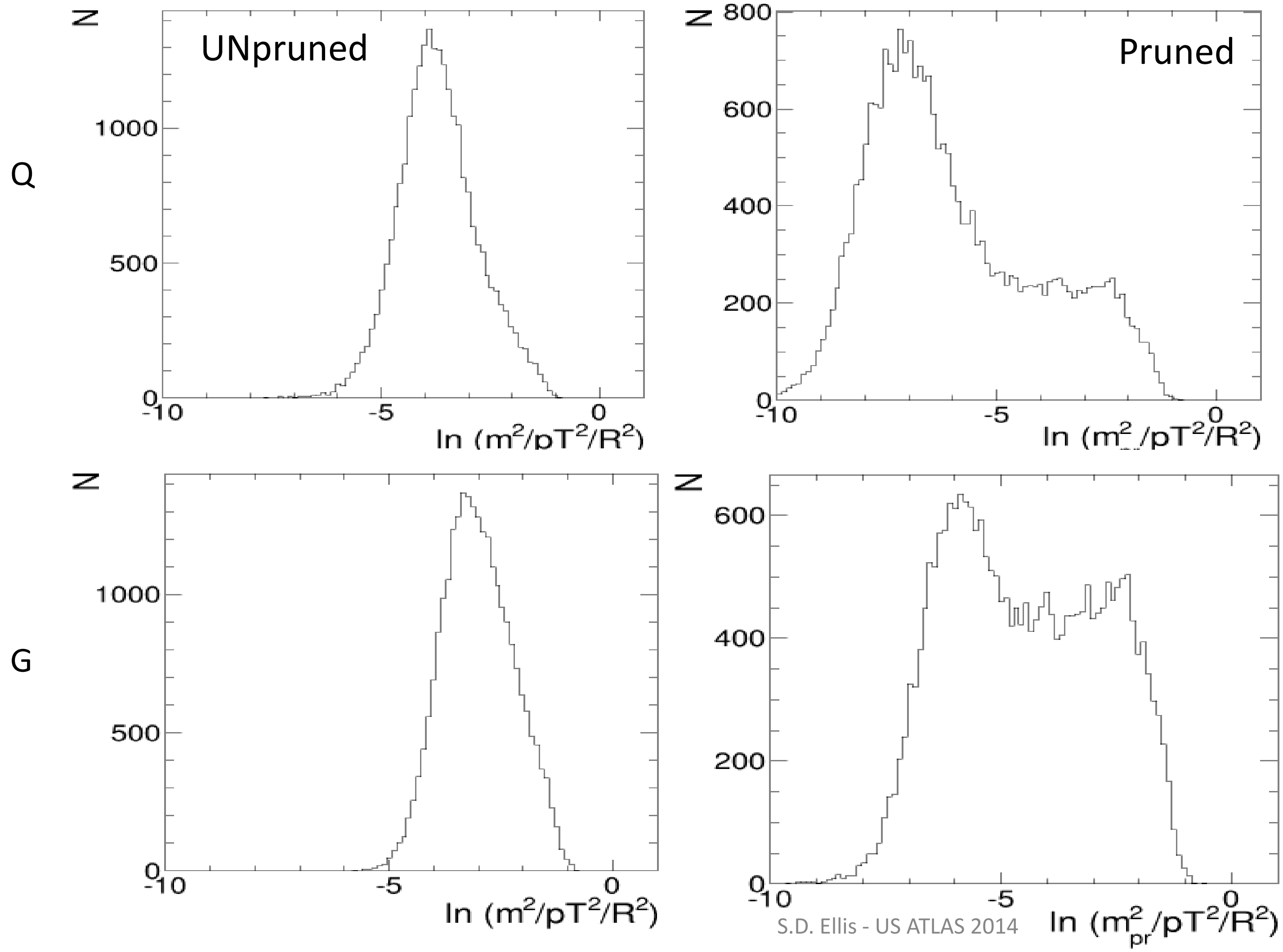
Shoulder clear (> 0.1) before and after pruning, falls off above 0.25;

Low mass peak very narrow after pruning;

Shoulder little changed by pruning;

Shoulder higher for gluons, ~ by CA/CF = 9/4;

Jet Mass distributions - Ln on x-axis, Linear on y-axis (focus on small values)



Gluon jets are a bit more massive;

Pruning moves peak to lower mass;

Shoulder very clear after pruning;

Shoulder higher for gluons, ~ by CA/CF = 9/4;

m/pT/R is good variable for comparing distributions, removes the common kinematics;

Pruning at ATLAS – Comments/Explanations (a cautionary tale)

A dramatic contrast (to my thoroughly biased eye) between the CMS and ATLAS jet grooming/tagging analyses as reported at BOOST 2013 and the Boosted Boson Workshop (CERN, 3/25/14) –

$\Rightarrow$ CMS analyses finds jet pruning is **very** effective

$\Rightarrow$ ATLAS finds pruning is **not** very effective!

☹☹☹☹ at UW!!!!!

The following comments attempt to explain this difference between the two collaborations.

Pruning Refs: 0912.0033, 0903.5081

A Brief Review of Pruning

- Like other groomers, given a jet (identified by some generic jet algorithm like AkT, kT or C/A) pruning attempts to remove from the jets those constituents that are unlikely to be ``associated'' with the jet or at least carry no significant/useful information.

- In particular, we want the mass of the resulting pruned jet to be small if we start with an every-day QCD jet, and near the particle mass if we start with a jet containing the decay products of a heavy particle.

- Pruning will can remove much of the uncorrelated contributions from UE and PU that make significant contributions to the jet mass.

Basic Idea of Pruning -

- Prune (remove) those constituents of the original jet that are:
  soft
  large angle

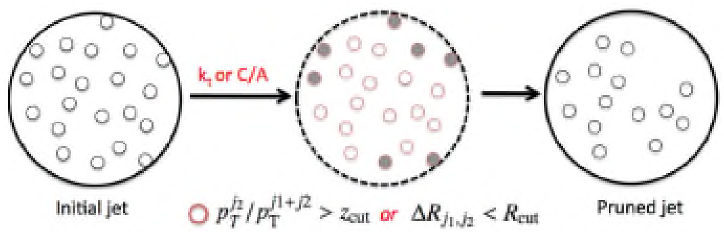
- These soft, large angle constituents are (statistically) less likely to be correlated with the energetic constituents in the jet and yet can still make measureable contributions to the mass

- Soft, small angle constituents can also be uncorrelated, but make a small contribution to the mass

- Most configurations that arise from actual heavy particle decay will not tend to be pruned (not all, but most).

Pruning in Action -

- Given the list of constituents in a jet, remerge using the kT or C/A algorithm



- At each potential merging step, j+k $\rightarrow$ l, check for
  soft - $p_k/p_l < z_{cut}$ ($p_k < p_j$)

  large angle - $\Delta R_{jk} > R_{cut} * (2m_{jet}/p_{jet})$,
  where $2m_{jet}/p_{jet}$ is angular scale **set by jet itself**

- If **both** cuts are satisfied, prune (remove) constituent k and proceed

- **Larger** z_{cut} and **smaller** R_{cut} values correspond to more **aggressive** pruning

- The level of pruning tends to be determined by the **LESS** aggressive of the two parameters (since we must satisfy **both** cuts)

Default Parameters

- The original studies (0912.0033) suggested

  R_{cut} = 0.5 (kT & C/A) $\Rightarrow \Delta R > m_{jet}/p_{jet}$

  z_{cut} = 0.1 (C/A)

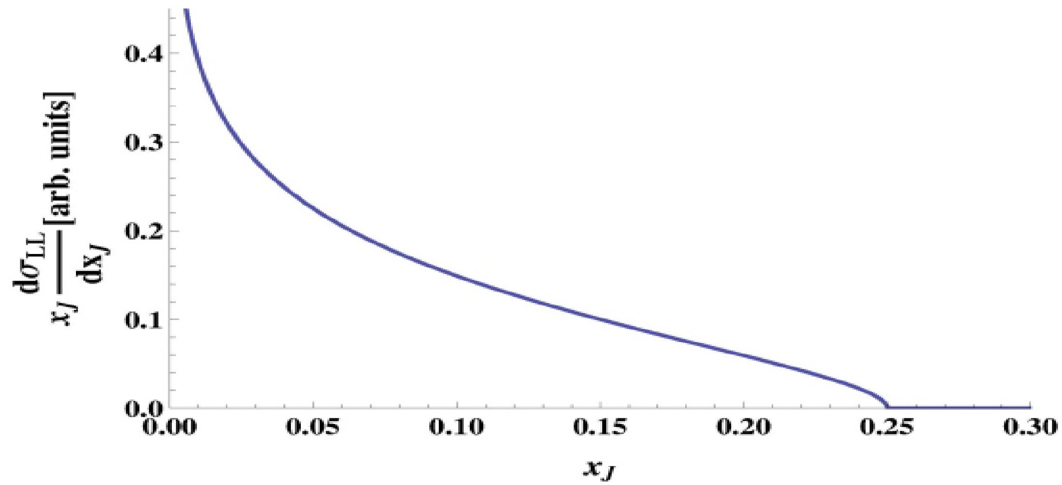
  z_{cut} = 0.15 (kT, since nearby soft constituents are merged early and are no longer as soft)

- Also, to ensure that decay products of “signal” particle “fit” in jet (size R) and are rarely pruned,

  require $m_{particle}/p_{jet}/R$ be less than 0.5

Naïve NLO 2-body analysis

- Distribution vanishes above $x_J = (m_{particle}/p_{jet}/R)^2 = 0.25$ (from 0912.0033)

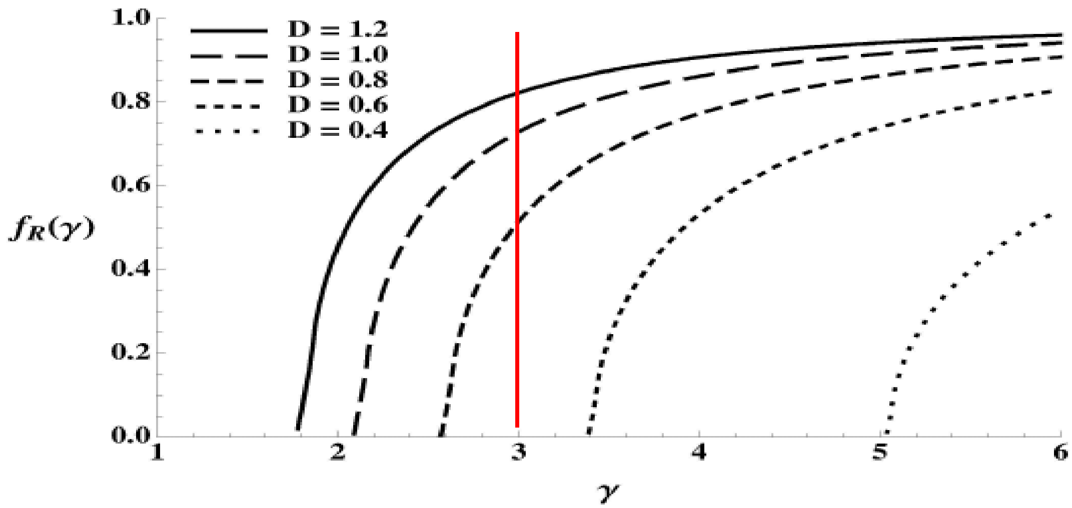


- With more complete showering the distribution goes past 0.25 but the "shoulder" is rapidly falling there

- Recall earlier QCD jet distributions from Nhan

Also (more forgotten history?)

- Recall Figure 11 from 0912.0033, which shows the fraction of two-body decays that "fit" in a jet of size R (=D).

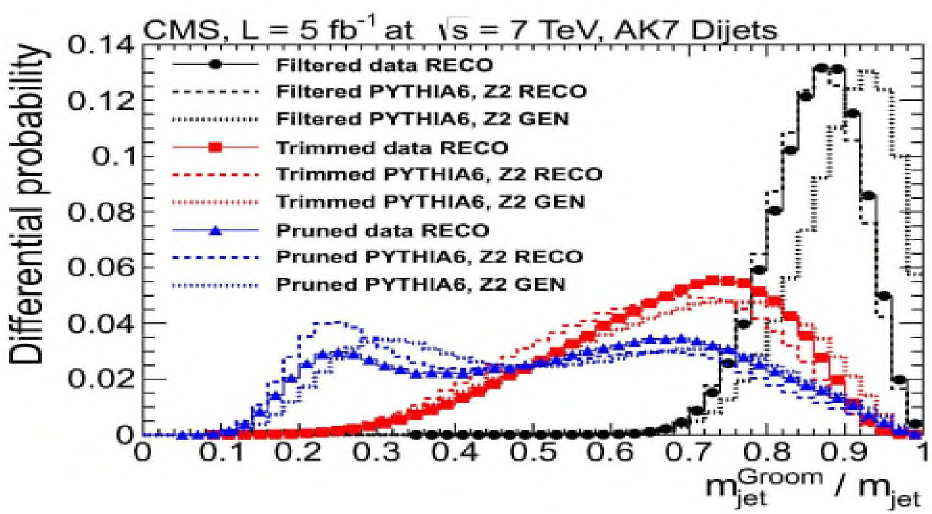


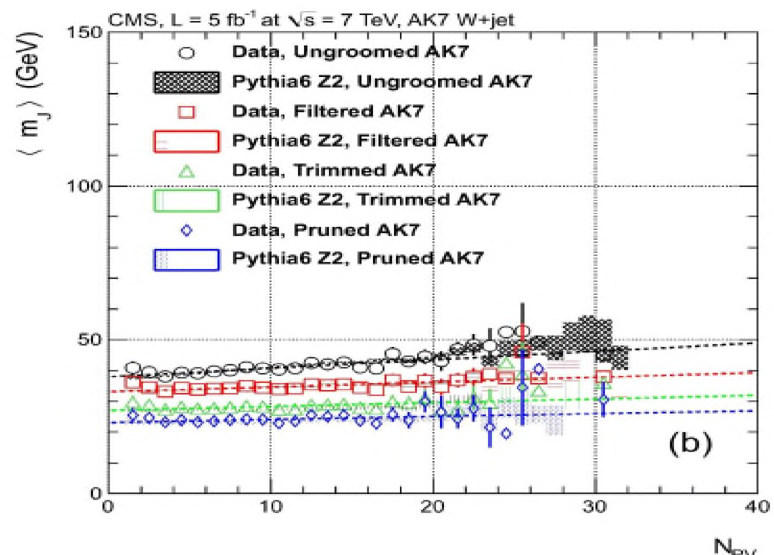
- Consider a W with pT of order 250 to 300 GeV/c, and thus a γ of about 3.
- About 50% of the W's don't fit for R = 0.8, while about 15% still don't fit for R = 1.2.
- The W's that don't fit will populate the low mass bump.
- The situation is substantially improved for larger pTs (> 450 GeV, γ > 5).

Pruning at CMS, e.g., 1303.4811

- Prune with C/A using parameters
  z_{cut} = 0.1 (default)
  R_{cut} = 0.25, $\Delta R > 0.5\ m_{jet}/p_{jet}$ (aggressive)

- Conclude that Pruning is most aggressive groomer studied -



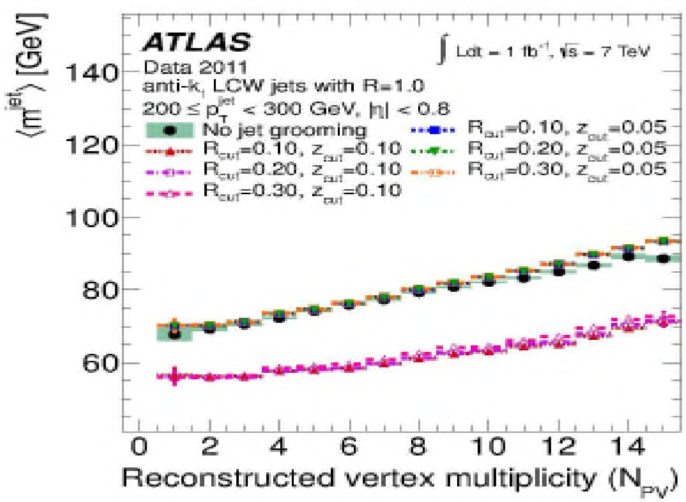


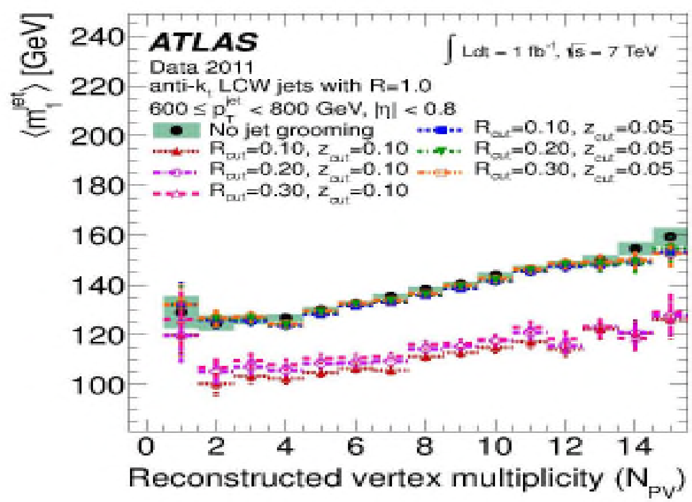
Compare - Pruning at ATLAS – 1306.4945

- Prune with kT using parameters

z_{cut} = 0.1, 0.05 (less aggressive than default = 0.15)

R_{cut} = 0.1, 0.2, 0.3, $\Delta R > R_{cut}\,(2m_{jet}/p_{jet})$ (more aggressive than default)





- Conclude pruning is **NOT** very effective groomer – **AS EXPECTED** due to parameter choices

Latest ATLAS results – ATL-PHYS-PUB-2014-004 (3/26/14)

- Study 5 combinations of algorithm + groomer, :
  AK10 + trim, C/A12 + BDRS, C/A12 + BDRS-A,
  C/A8 + C/A prune (0.1,0.5 = default),
  C/A8 + kT prune (0.1,0.5 less aggressive than default as above)

  in 3 pT bins using 7 kinematic variables for W tagger

- First do ROC study of algorithm + groomer: define groomed jet mass window to keep 68% of signal (W) and check QCD fake rate (MC data, check that found jets match truth jets almost all of time)

ATL-PHYS-PUB-2014-004

- Results (Table 1) - ε_{QCD} = fake rate, $\mathcal{P}^{+\mathcal{U}}_{-\mathcal{L}}$= mass window

Jet collection	$200 < p_T^{turth} < 350$ GeV		$350 < p_T^{truth} < 500$ GeV		$500 < p_T^{truth} < 1000$ GeV	
	$\mathcal{P}^{+U}_{-L}$ [GeV]	ϵ_{QCD}	$\mathcal{P}^{+U}_{-L}$ [GeV]	ϵ_{QCD}	$\mathcal{P}^{+U}_{-L}$ [GeV]	ϵ_{QCD}
Trimmed	82^{+10}_{-18}	$13.6 \pm 0.1\%$	80^{+8}_{-8}	$9.9 \pm 0.2\%$	82^{+10}_{-10}	$8.4 \pm 0.5\%$
BDRS	78^{+14}_{-16}	$14.8 \pm 0.1\%$	80^{+6}_{-18}	$7.8 \pm 0.2\%$	76^{+6}_{-14}	$6.7 \pm 0.5\%$
BDRS-A	78^{+12}_{-16}	$23.2 \pm 0.1\%$	82^{+8}_{-14}	$15.9 \pm 0.3\%$	80^{+10}_{-14}	$10.0 \pm 0.6\%$
C/A-pruned	78^{+22}_{-40}	$28.9 \pm 0.1\%$	78^{+8}_{-12}	$8.0 \pm 0.2\%$	78^{+6}_{-14}	$6.5 \pm 0.5\%$
k_t-pruned	84^{+22}_{-42}	$40.7 \pm 0.2\%$	82^{+16}_{-14}	$16.9 \pm 0.3\%$	82^{+18}_{-14}	$16.4 \pm 0.7\%$

- kT-pruned performs less well (larger ε_{QCD}) than C/A pruned, **as expected** due to (poor) parameter choice

- In largest 2 pT bins C/A pruning is (effectively) tied for **most** aggressive groomer, smallest ε_{QCD} (like CMS)

What happens in the lowest pT bin?

Recall that
$\mathcal{P}^{+\mathcal{U}}{}_{-\mathcal{L}}$= mass window

Jet collection	$200 < p_T^{turth} < 350$ GeV		$350 < p_T^{truth} < 500$ GeV		$500 < p_T^{truth} < 1000$ GeV	
	$\mathcal{P}^{+U}_{-L}$ [GeV]	ϵ_{QCD}	$\mathcal{P}^{+U}_{-L}$ [GeV]	ϵ_{QCD}	$\mathcal{P}^{+U}_{-L}$ [GeV]	ϵ_{QCD}
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Pruned mass window
for lowest pT bin is **TWICE** the size of the other mass windows, essentially **DOUBLES** the fake rate!

Why is this large mass window needed?

Because these low pT (low boost) W's are difficult to fit in a small R (0.8) jet, i.e., we are on the **low** efficiency edge of the shoulder
– should plot the distribution versus $(m_{particle}/p_{jet}/R)^2$ to check!

Comments:

- Pruning is observed to be performant at ATLAS when **appropriate** parameter values are chosen, i.e., consistent with CMS

- Analysis of lowest pT bin needs to be clarified (boost too small for small R?)

- ATLAS study has kinematic variable correlation information, but currently difficult to interpret due to multiple “knobs” being turned at once (e.g., vary algorithm AND R values)

- **ATLAS folks should talk to your Theory friends more often!!**

Qjets & Volatility (Γ) (works for ATLAS, ATLAS-CONF-2013-87)

- Qjet idea is that there is no "correct" algorithm for pruning (or grooming in general);
- So prune several times with a "random" set of algorithms;
- Generates a mass DISTRIBUTION for each jet;
- The width of this distribution is the volatility Γ;
- A jet containing a real decay will exhibit small volatility, while QCD jets exhibit larger volatility;
- Now compare Q & G jets (more BOOST 2013 Working Group plots) -

ASIDE: A new paper on Qjets statistics is coming soon. Original = 1201.1914. See related "Telescoping", 1407.2892

Qjets details (from ATLAS-CONF-2013-87)

1. Start with a jet found by any jet algorithm and collect the constituents into a list.

2. Compute a set of weights ω_{ij}, which reflect how likely a pair of four-vectors is to be merged, for all pairs of four-vectors. Here, the weights are chosen to be defined as:

$$\omega_{ij}^{(\alpha)} = \exp\left\{-\alpha\frac{d_{ij} - d^{\min}}{d^{\min}}\right\} \tag{3}$$

   where α is the *rigidity* which controls the sensitivity of the pair selection to the random number generation, $d_{ij} \equiv \Delta R_{ij}^2 = \Delta y_{ij}^2 + \Delta\phi_{ij}^2$ the distance measure for the (i, j) pair and $d^{\min}$ the minimum of the distance between all pairs. Then the probability $\Omega_{ij} = \omega_{ij}/N$ is defined, where $N = \sum \omega_{ij}$.

3. Instead of finding the single minimum d_{ij} as in Equation 1, generate a random number, using Equation 3 as a probability density function, and choose a pair of four-vectors as above according to the probabilities Ω_{ij}.

4. Consider this pair for merging, and veto (as in normal pruning) if they fail the cuts in Equation 2.

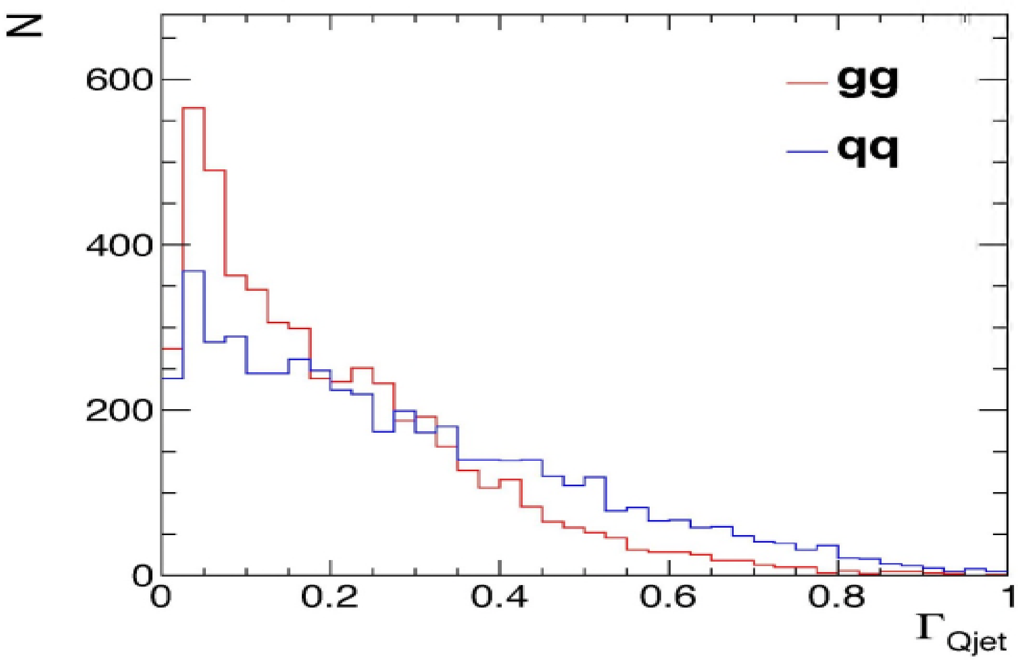
5. Continue until all pairs are merged: the result is one Q-jet. The algorithm can be repeated multiple times to generate a distribution of Q-jets for every jet.

1) $d_{ij} = \min\left(p_{\mathrm{Ti}}^{\beta}, p_{\mathrm{Tj}}^{\beta}\right)\frac{\Delta R_{ij}^2}{R^2}$

$d_{iB} = p_{\mathrm{Ti}}^2$

2) $z_{ij} = \frac{\min(p_{\mathrm{T},i}, p_{\mathrm{T},j})}{|\vec{p_{\mathrm{T},i}} + \vec{p_{\mathrm{T},j}}|} < z_{\mathrm{cut}}$ and $\Delta R_{ij} > d_{\mathrm{cut}}$.

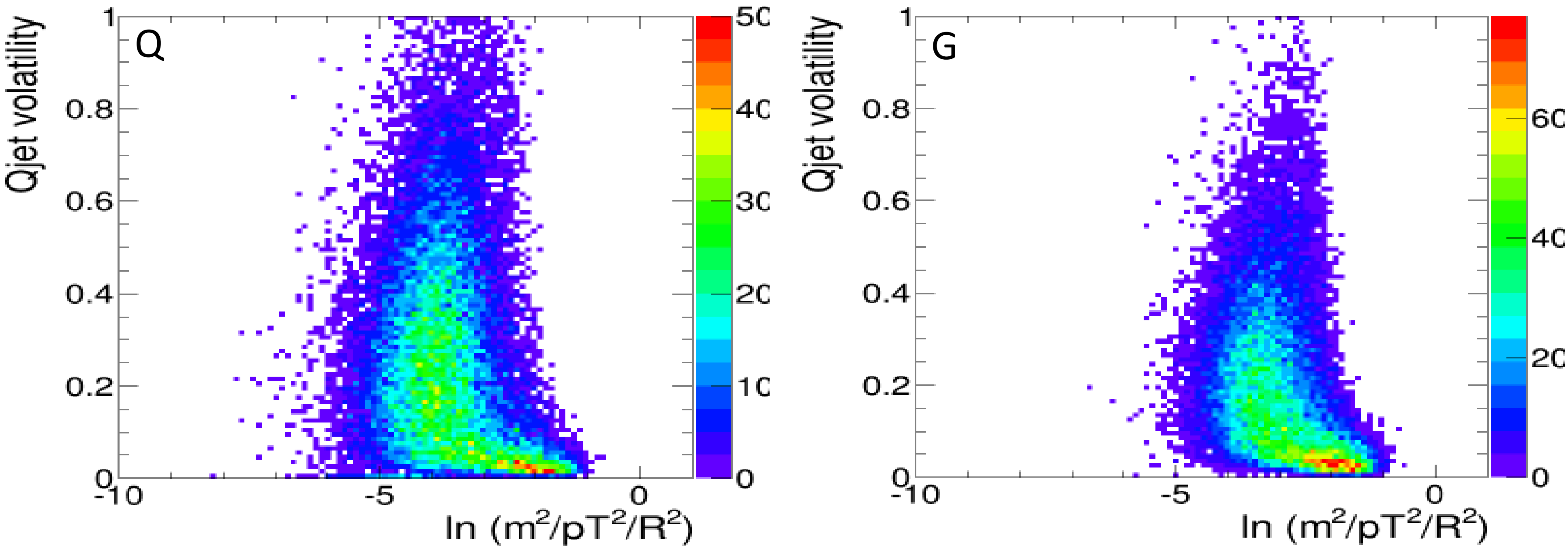
Gluons are LESS volatile! Why??



1) Shoulder region is higher and peak is lower for gluons, so gluon jets have larger fraction in shoulder;
2) Shoulder region jets have mass from energetic, wide angle emission;
3) Shoulder region jets exhibit smaller volatility;
4) Gluons jets are LESS volatile.

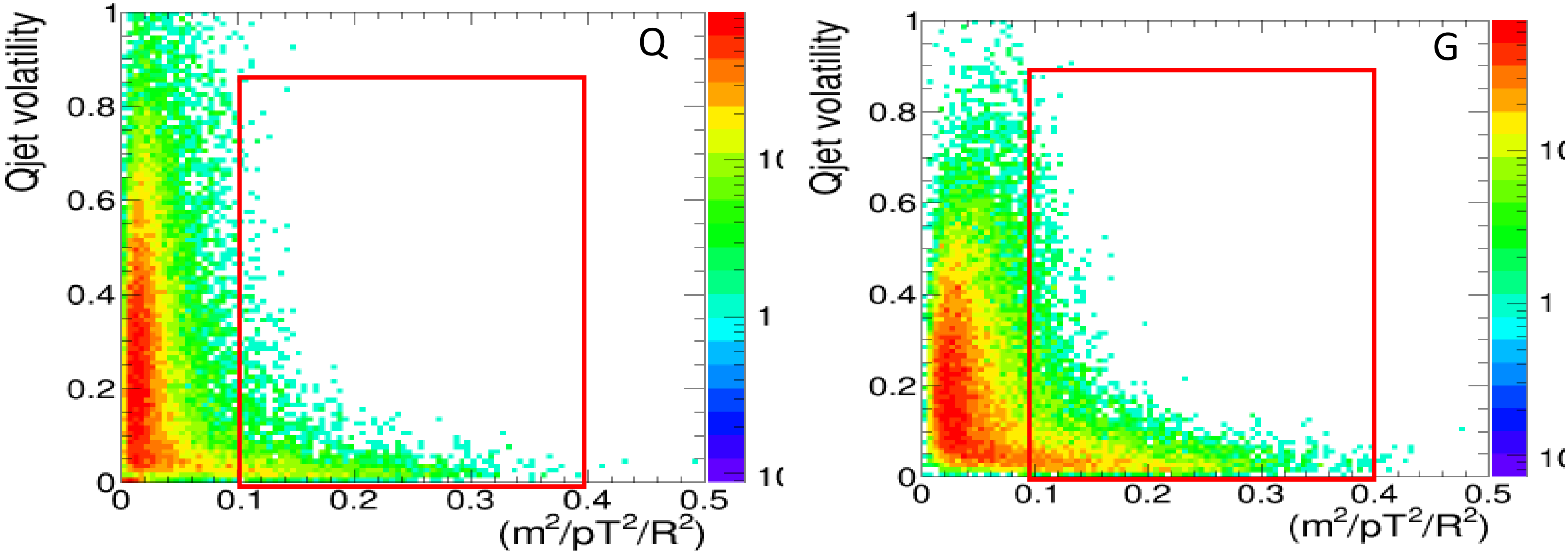
Look at this correlation in detail with 2-D scatter plots

UNpruned Γ_{Qjet} versus Ln m/pT/R (focus on small values)



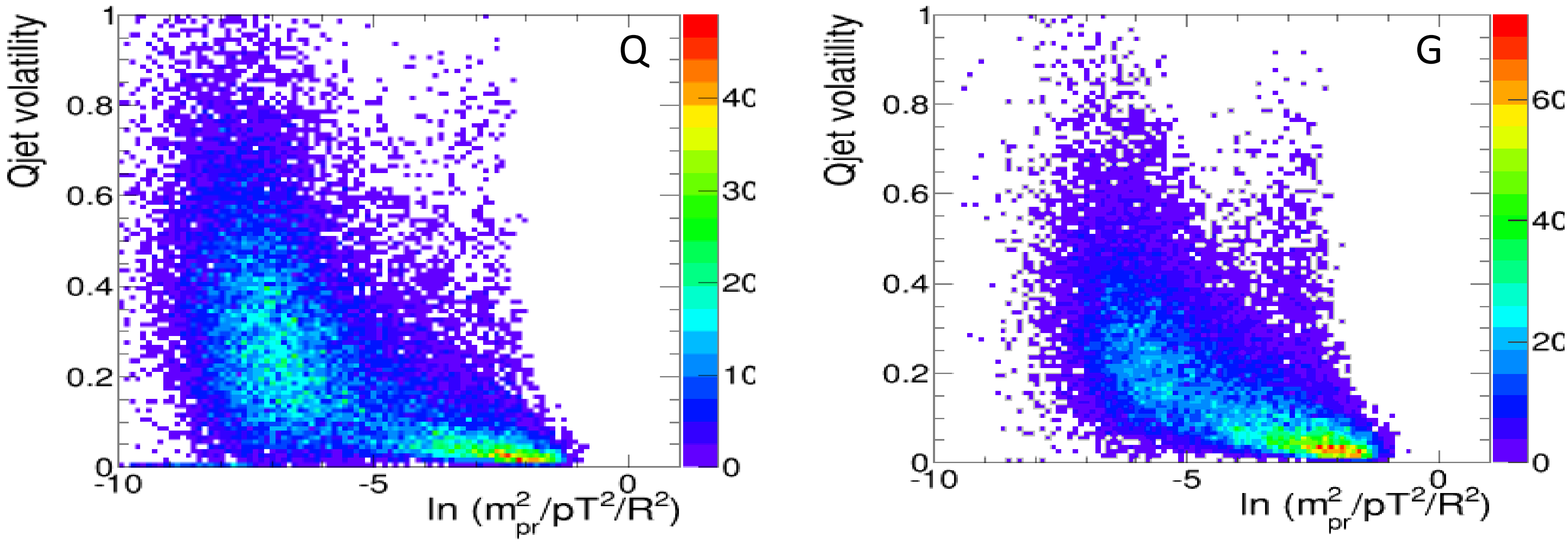
In both cases larger volatility is associated with smaller m/pT, where mass is generated by many soft emissions → different pruning yields different masses

UNpruned Γ_{Qjet} versus $(m/pT/R)^2$ (focus on larger values)



In both cases larger volatility is associated with smaller m/pT, and smaller volatility with the shoulder region ▭, the small but hard-to-beat BKG.

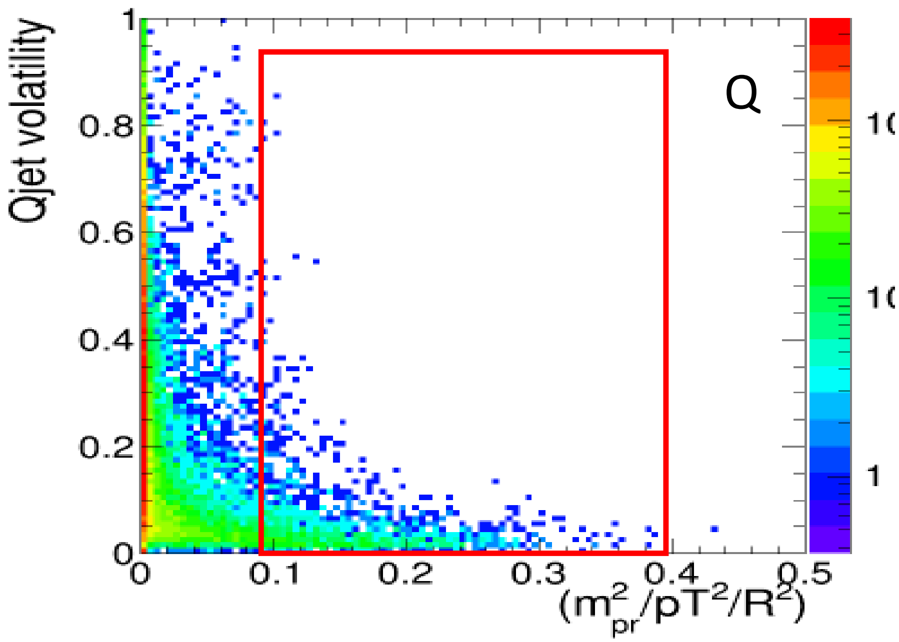
Pruned Γ_{Qjet} versus Ln m_{pr}/pT/R (focus on smaller values)

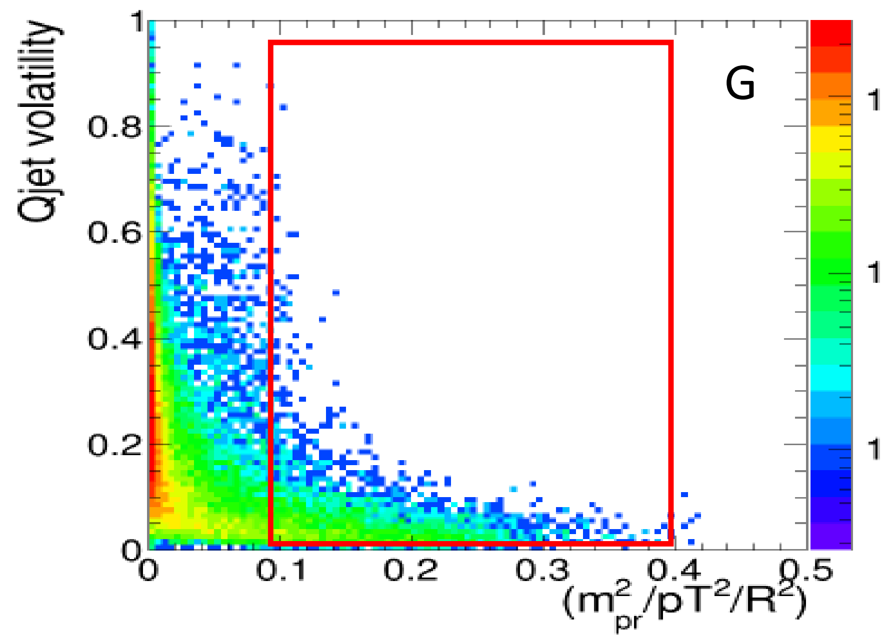


Pruned masses are smaller.

In both cases larger volatility is associated with smaller m/pT, i.e., with low mass peak; lower volatility in shoulder.

Pruned Γ_{Qjet} versus $(m_{pr}/pT/R)^2$ (focus on larger values)





In both cases larger volatility is associated with smaller m/pT, i.e., with low mass peak; lower volatility in shoulder .

Comments:

- Gluons exhibit smaller volatility due to

  larger fraction of jets in shoulder,
  smaller volatility in shoulder;

Suggestions:

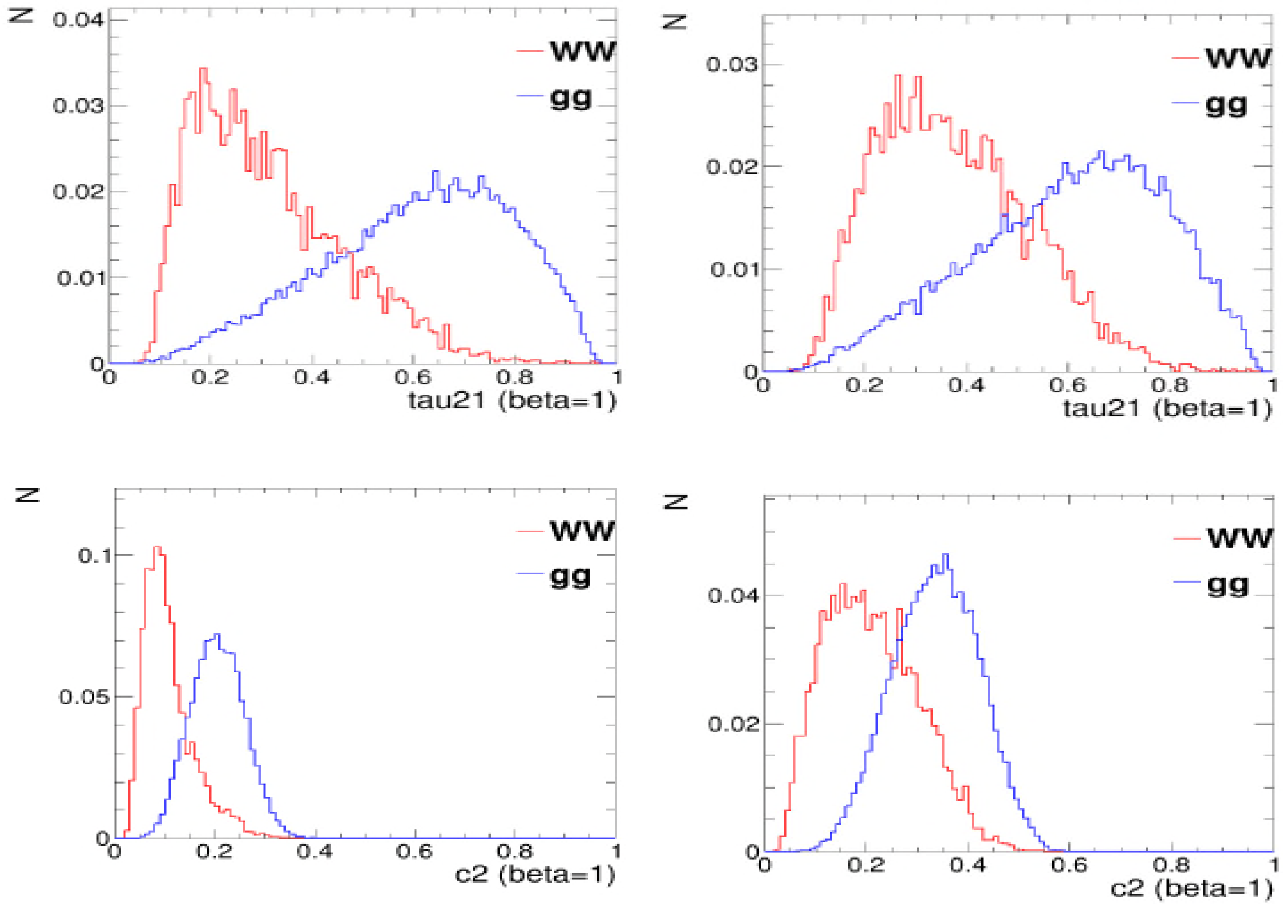
- Recommend using linear m/pT/R axis (although shoulder is probably most obvious in pruned log case).
- Recommend using log y-axis for jet counting distributions to see both low mass peak and shoulder.

Comparing W and Gluon jets

More from the BOOST 2013 Working Group

R dependence: pT = 500 GeV (AktTR jets)

R = 0.8 R = 1.2

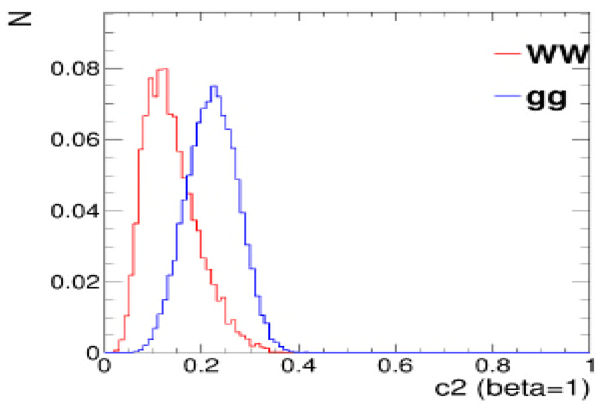


Only a slight shift to larger values, and similar for both samples. Slight degradation of separation, since W peaks broadens a bit more.

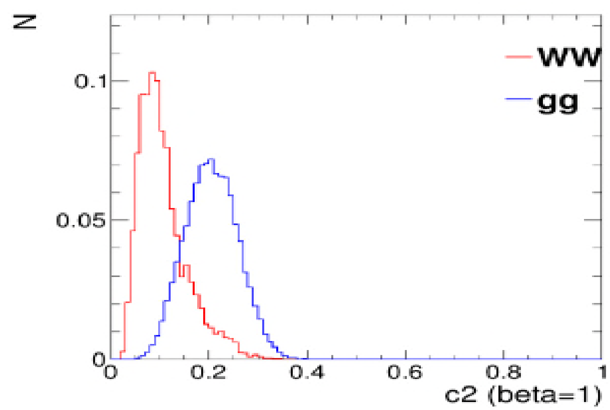
Much narrower distributions than for tau21 and at smaller R values. Shift with R is approximately linear as expected (Eq. 2.27 in 1305.0007). Broadening of peaks leads to slight degradation of separation.

pT Dependence, R = 0.8: $C_2(\beta=1)$

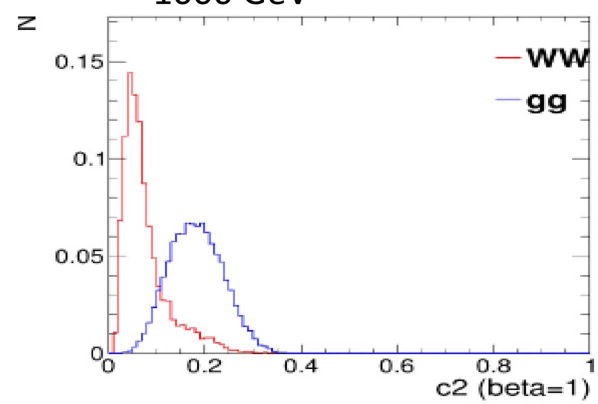
300 GeV



500 GeV



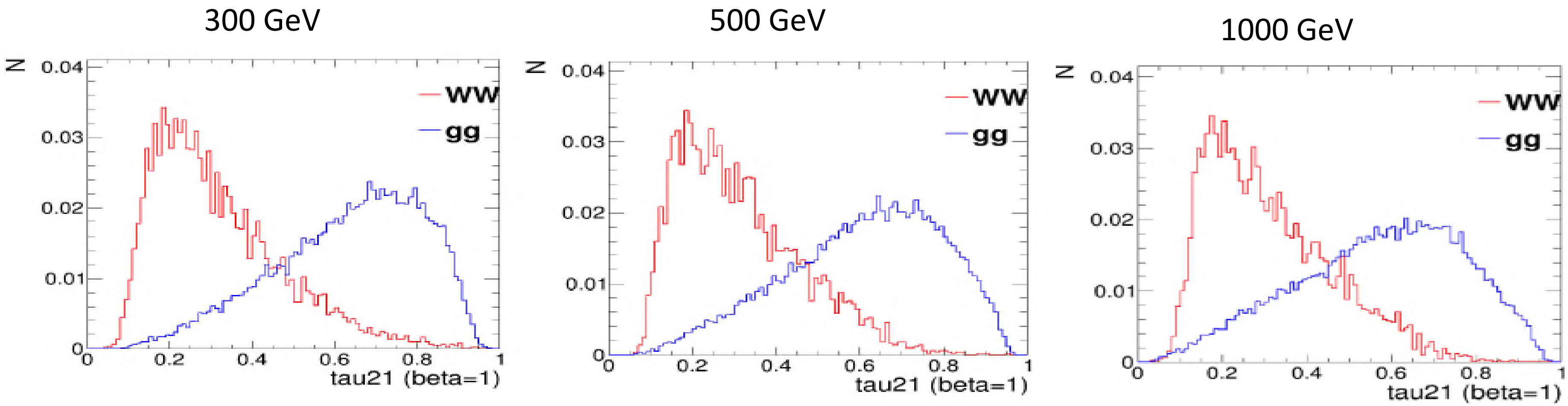
1000 GeV



The $C_2(\beta=1)$ gluon distribution shifts slightly to smaller values, and broadens slightly. Overall the $C_2(\beta=1)$ change with pT is quite small.

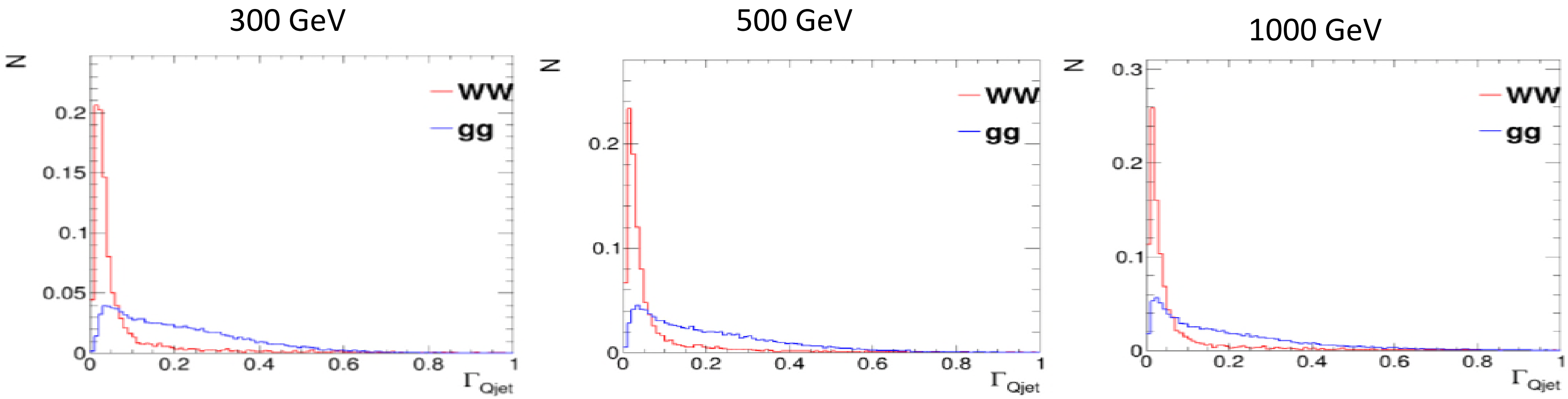
The $C_2(\beta=1)$ W distribution also shifts to slightly smaller values, but becomes substantially narrower, with an increase of about a factor of 2 in the peak value. This narrowing is presumably due to the fact that the angular size is driven by m_W/pT, which decreases as pT increases, and that $C_2(\beta=1)$ is linearly sensitive to this angle (compared to τ_{21}).

pT Dependence, R = 0.8: τ_{21}



In contrast to the $C_2(\beta=1)$ case, for τ_{21} there is very little variation of the distributions with pT. As already noted a large part of the difference is the extra angular dependence in $C_2(\beta=1)$ compared to τ_{21} (see Eq. 2.27 in 1305.0007). In τ_{21} essentially all of the kinematic and non-scaling dependence on pT cancels out.

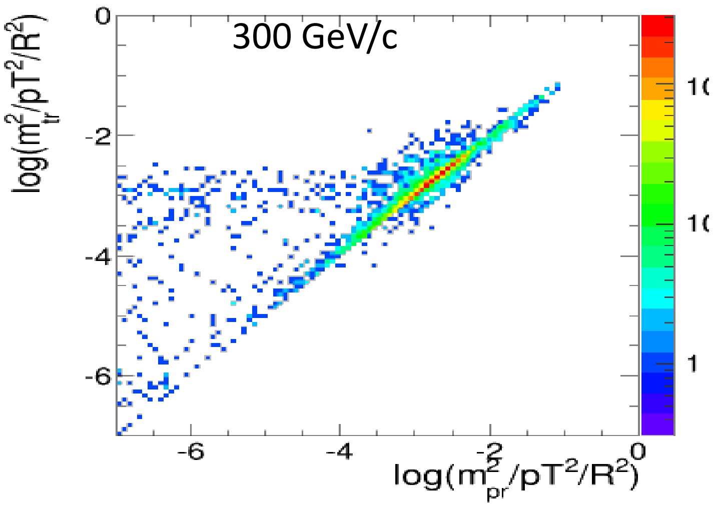
pT Dependence, R = 0.8: Γ_{Qjet}

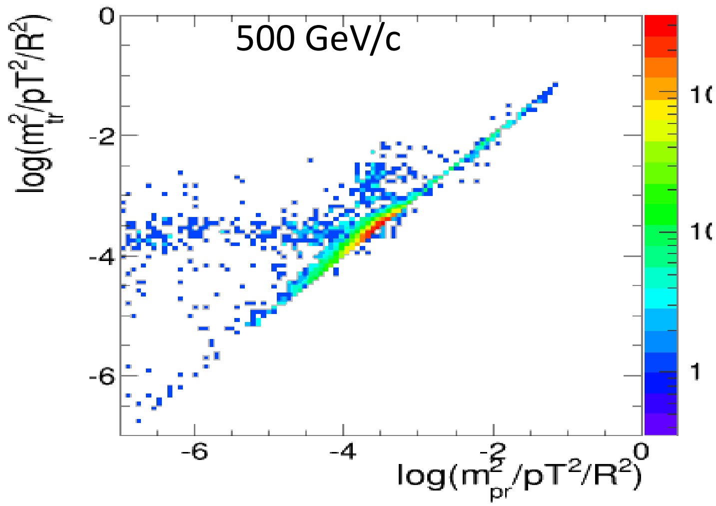


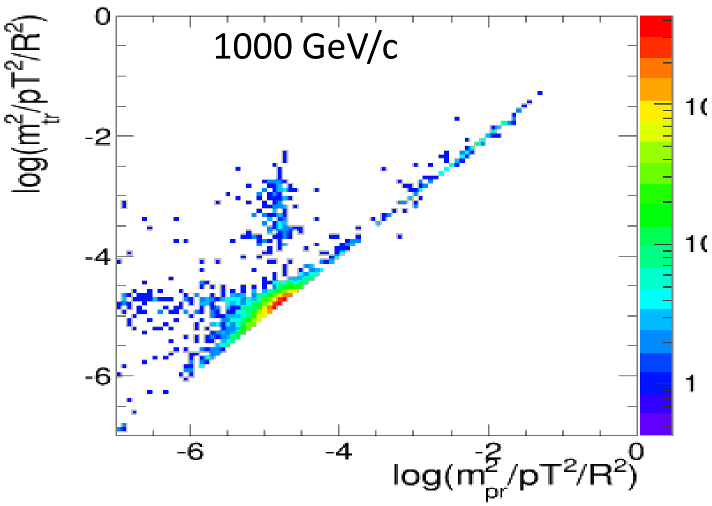
Here the impact of increasing pT is to lower the volatility for both QCD (g) and W jets. This is most dramatic for the gluon jets, which exhibit a slowly dropping large Γ_{Qjet} tail while the peak at small Γ_{Qjet} values (< 0.1) clearly increases. Overall the Γ_{Qjet} distributions for the two samples become more similar.

$\Rightarrow$ The (single variable) ROC curves for Γ_{Qjet} exhibit a small degradation with increasing pT.

Prune vs Trim vs pT for Ws (Correlations)

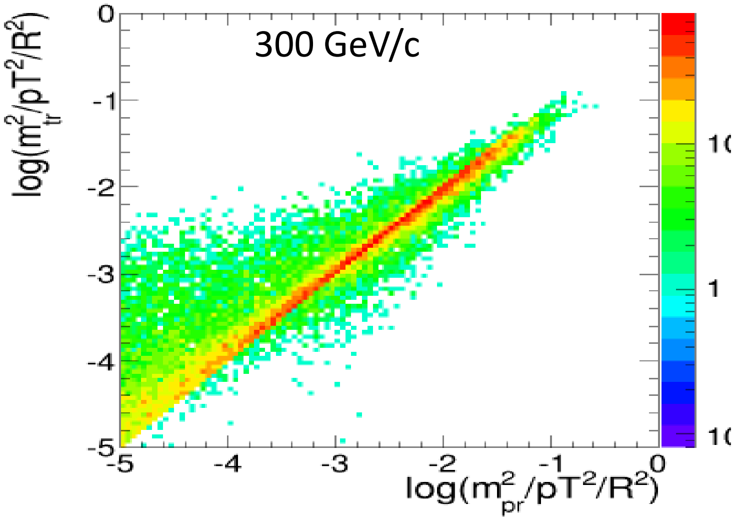


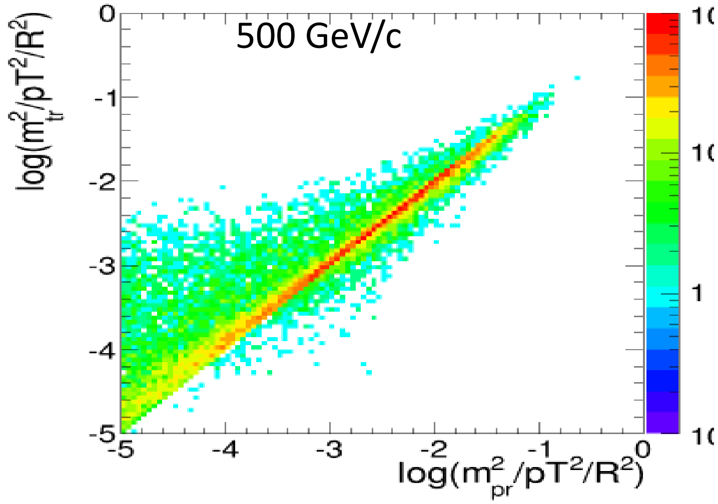


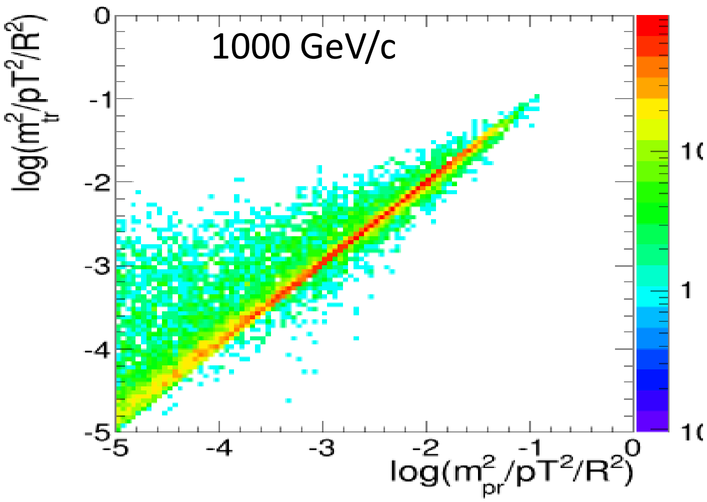


$m_{pr} \leq m_{tr}$ to good approximation;
uncorrelated ridges where one groomer gives W, but other does not, but for opposite reasons – pruning over-grooms while trimming under-grooms

Prune vs Trim vs pT for QCD





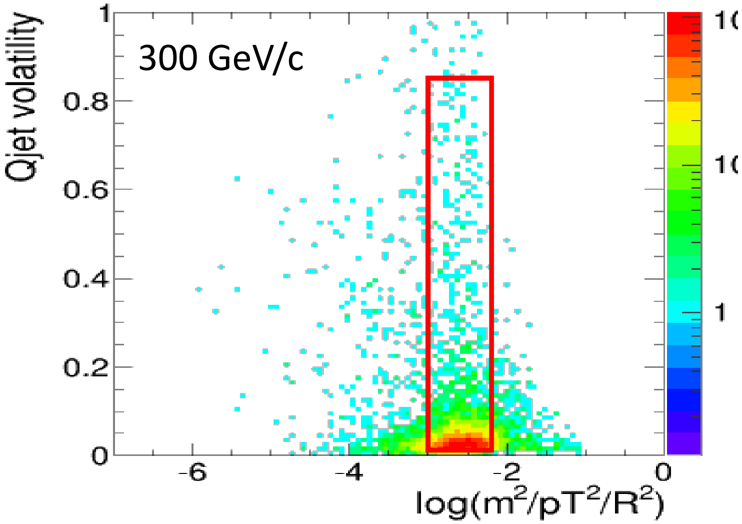


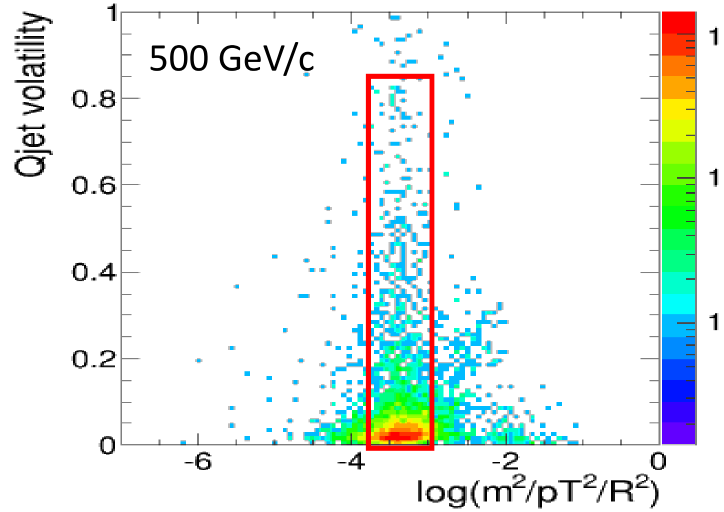
Still largely $m_{pr} \leq m_{tr}$ to good approximation;

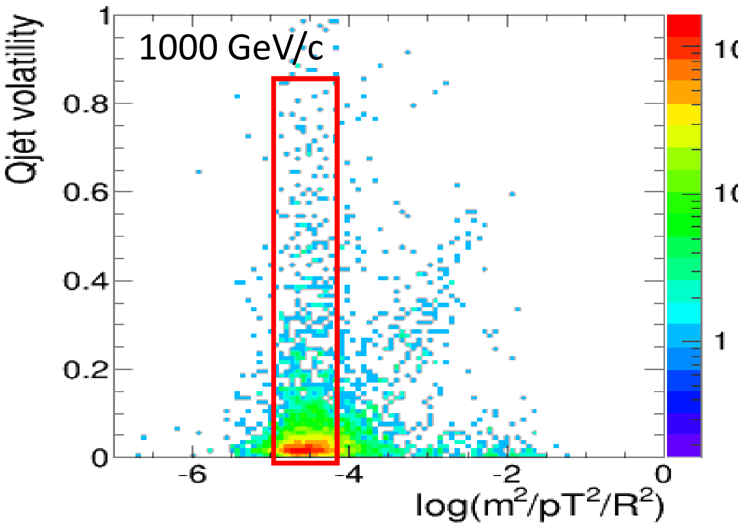
– pruning over-grooms while trimming under-grooms;

little change with pT

W volatility vs pT, unpruned mass

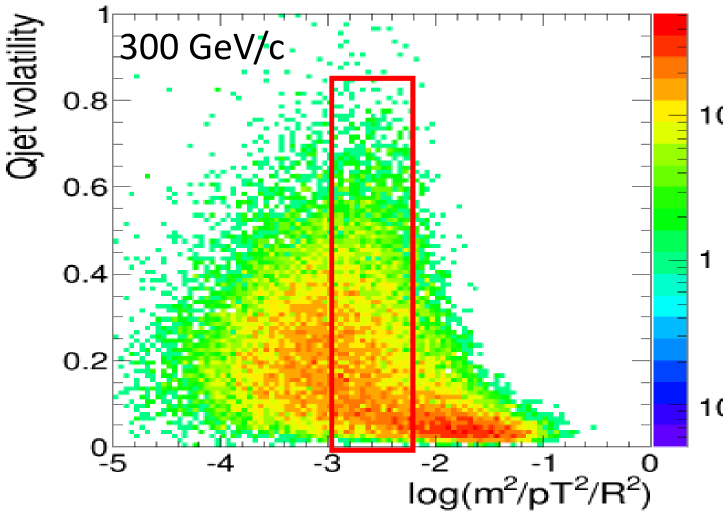


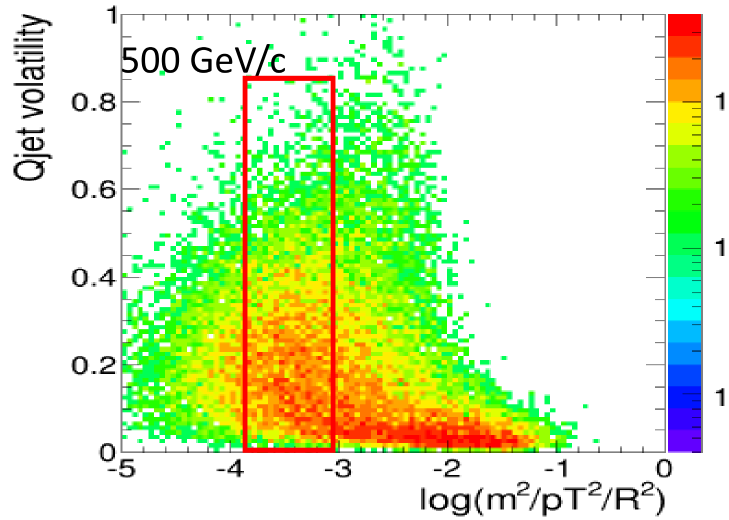


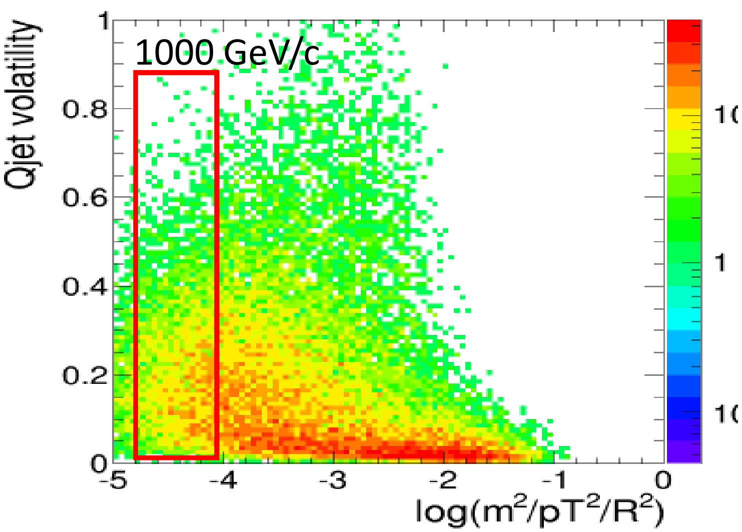


Volatility distribution broadens a little with pT generally, not so clear in peak region (= ▭)

QCD volatility vs pT, unpruned mass

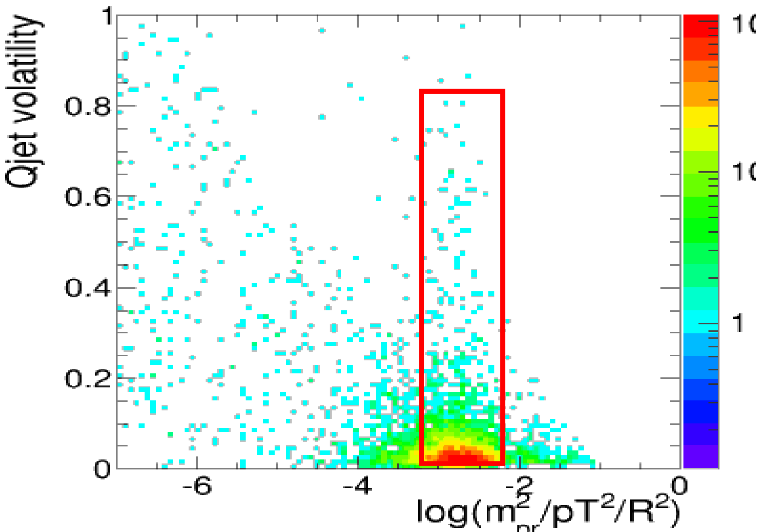


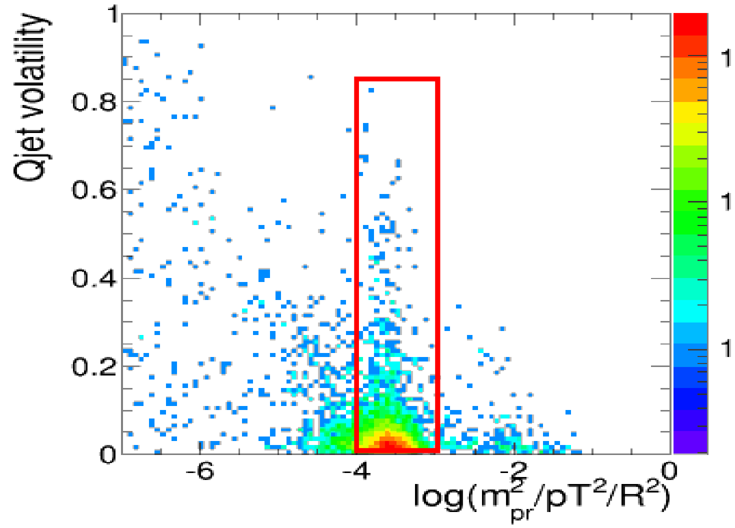


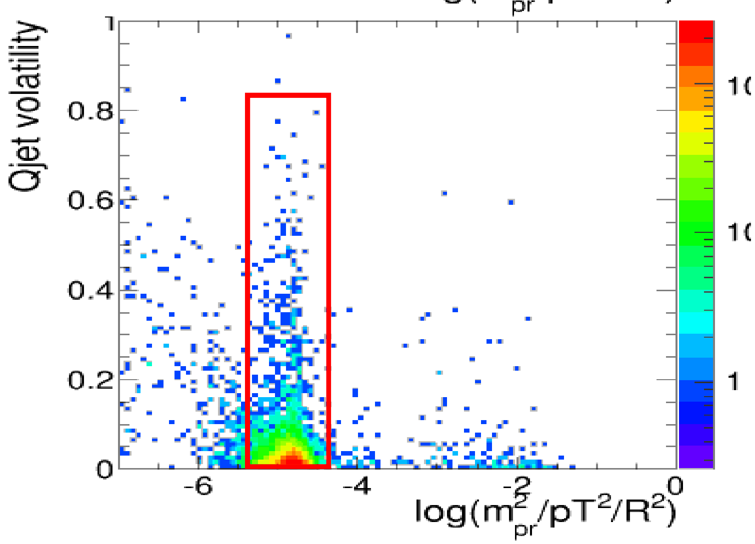


Generally QCD Volatility distribution sharpens with pT as observed in the volatility alone plots – presumably due to growing contribution of 1 “hard” emission with low volatility;
Combined pair actually improves with pT since QCD volatility distribution becomes flatter in the W mass bin

W volatility vs pT, pruned mass

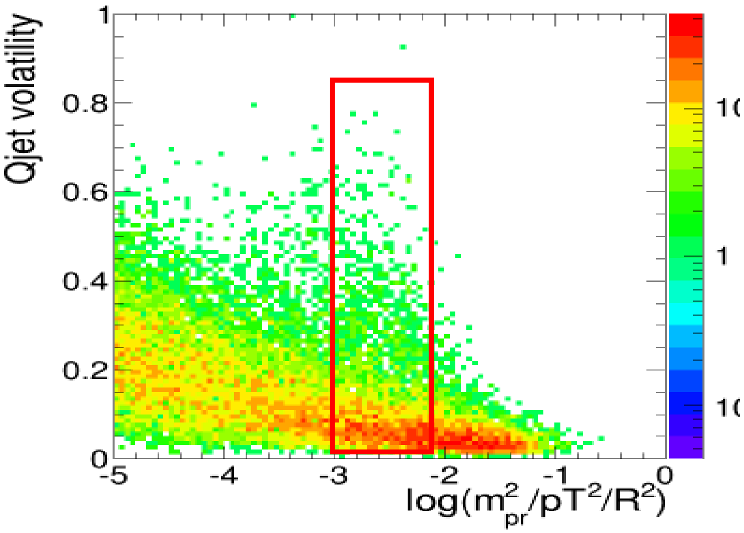


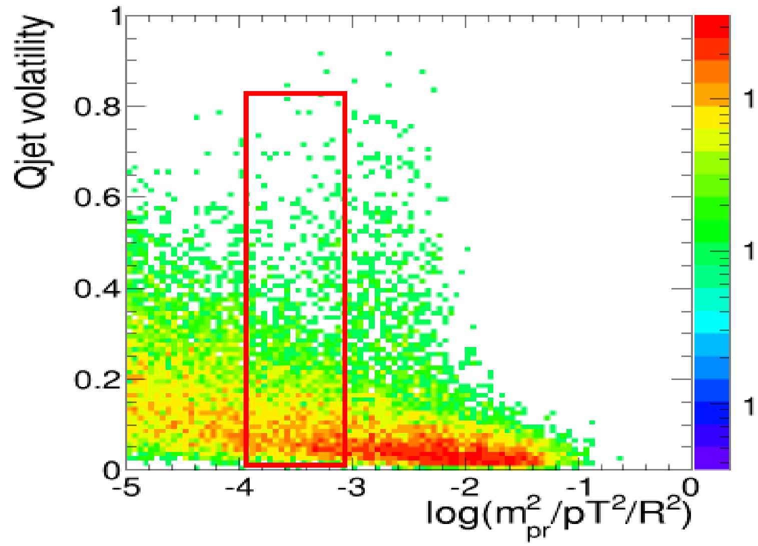


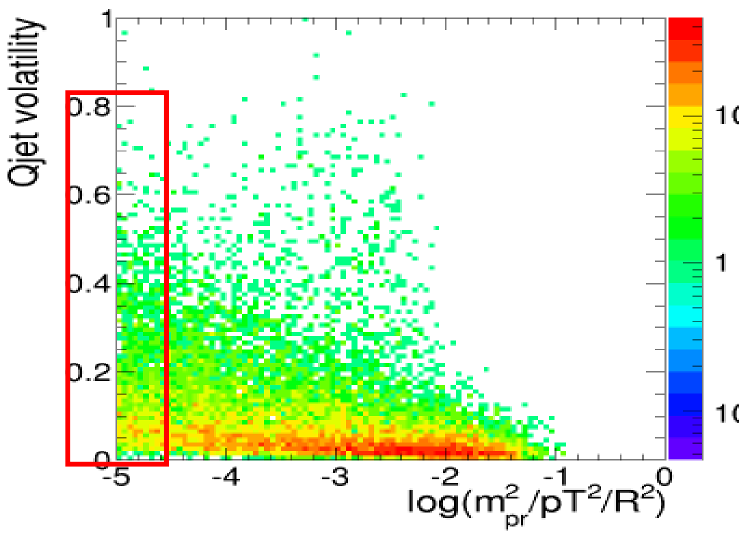


Distribution becomes more peaked at W mass

QCD volatility vs pT, pruned mass

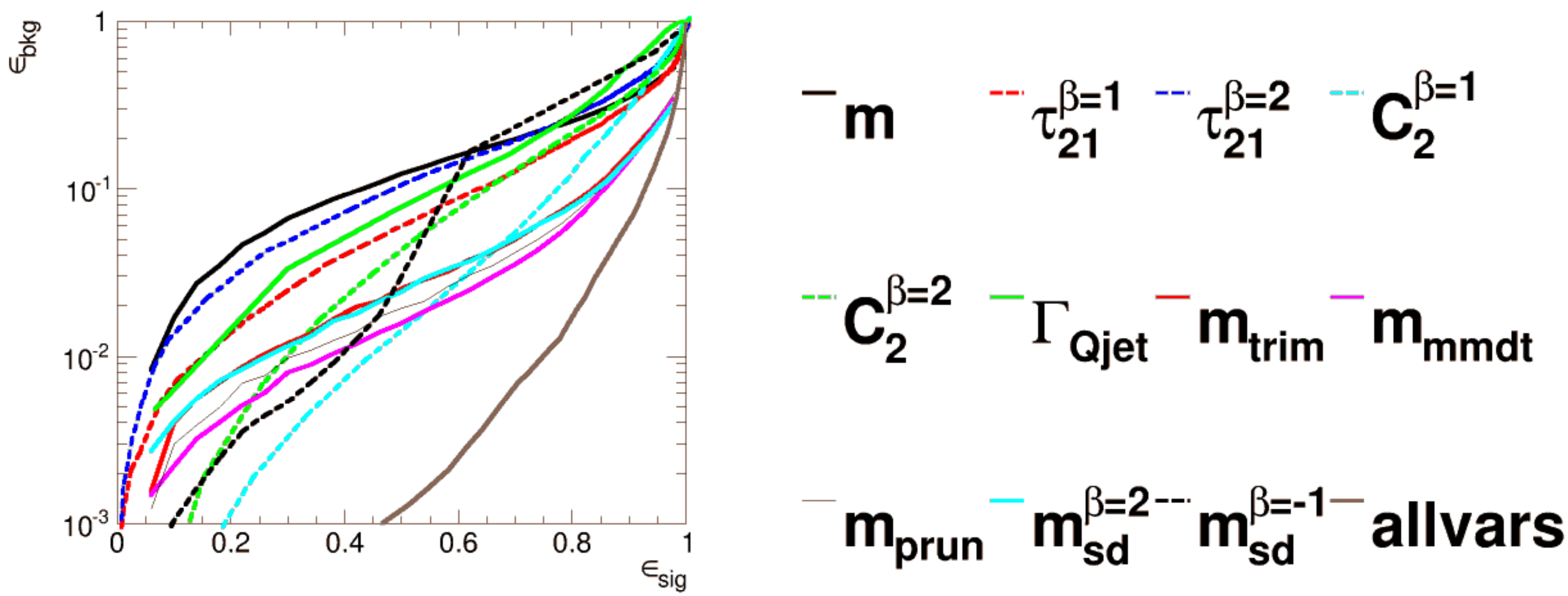






Correlated case should see larger improvement for volatility plus m_{pr}, as volatility distribution seems to be flatter in m_{pr} bin compared to m bin

ROC curves – single variable, W vs G jets, AkT8, 500 GeV

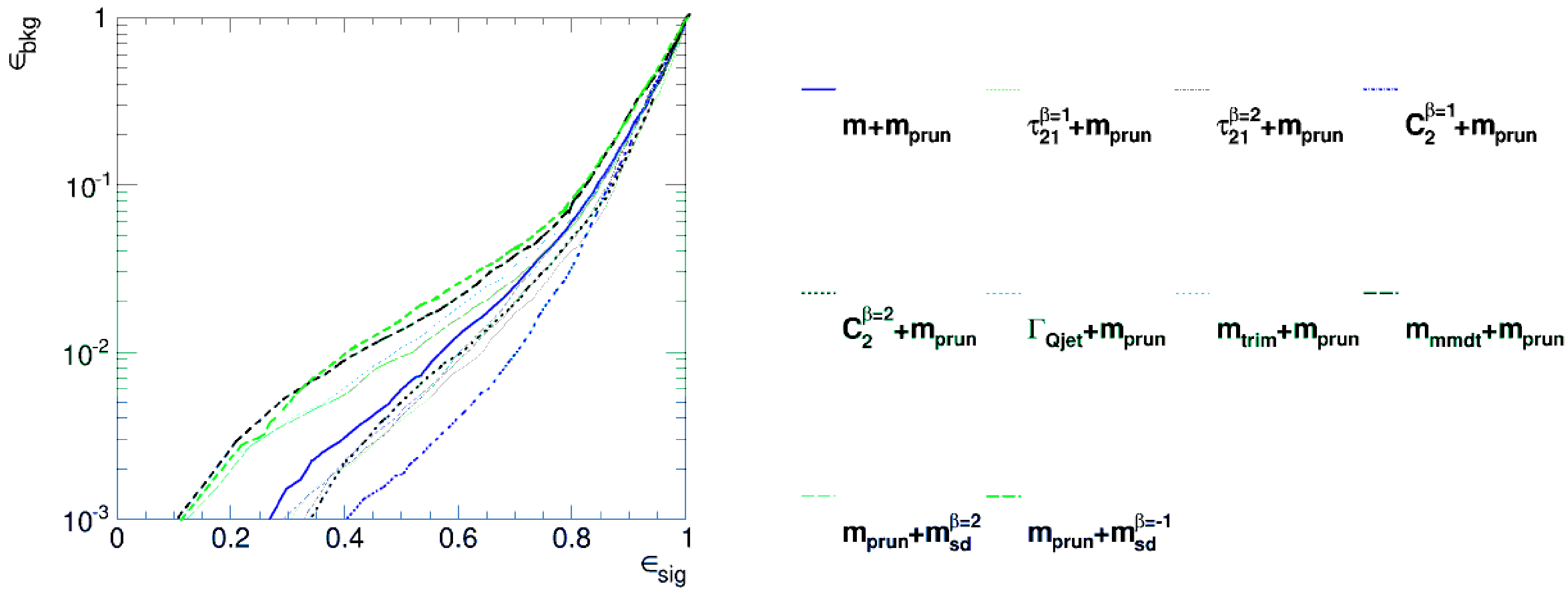


"Similar" curves for all

All better than just ungroomed mass

Improved by combining variables

Combine variables, e.g., m_{prun} +X



Discrimination improves on using two variables, especially a groomed mass plus a shape

Comments:

- Broad features of performance of groomers and taggers relatively insensitive to pT and R

- Details of performance of groomers and taggers depend on R and PT

  and on the correlations between the variables

- The BOOST 2013 report will provide many details and (hopefully) explanations on Q vs G, Q vs G and top vs QCD

Final Comments:

- Run II will see extensive (and successful) use of Jet Substructure tools! Both for searches and for tagging (and for the combination). Especially by using several variables in combination.

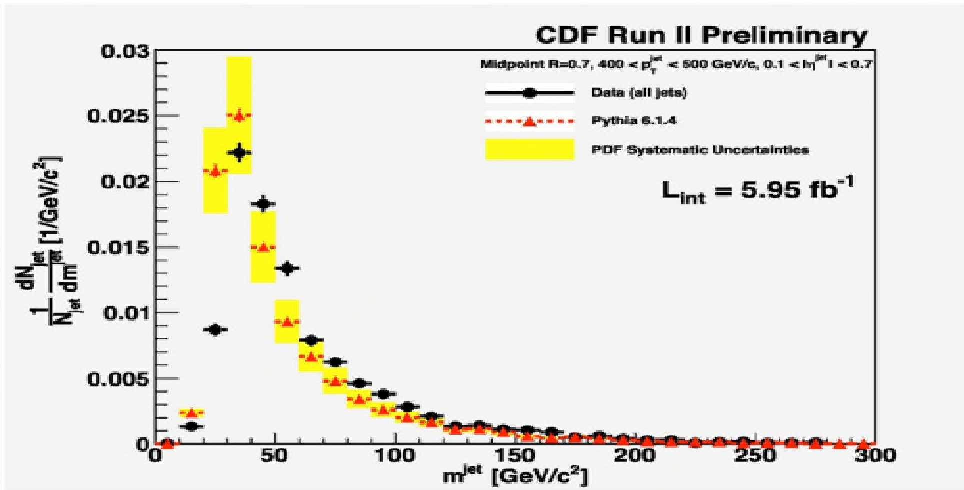
- To make the most the most of these tools theory and experiment must work **together**.

ASIDE

- Have ATLAS and CMS published jet results using the **SAME** algorithm yet?

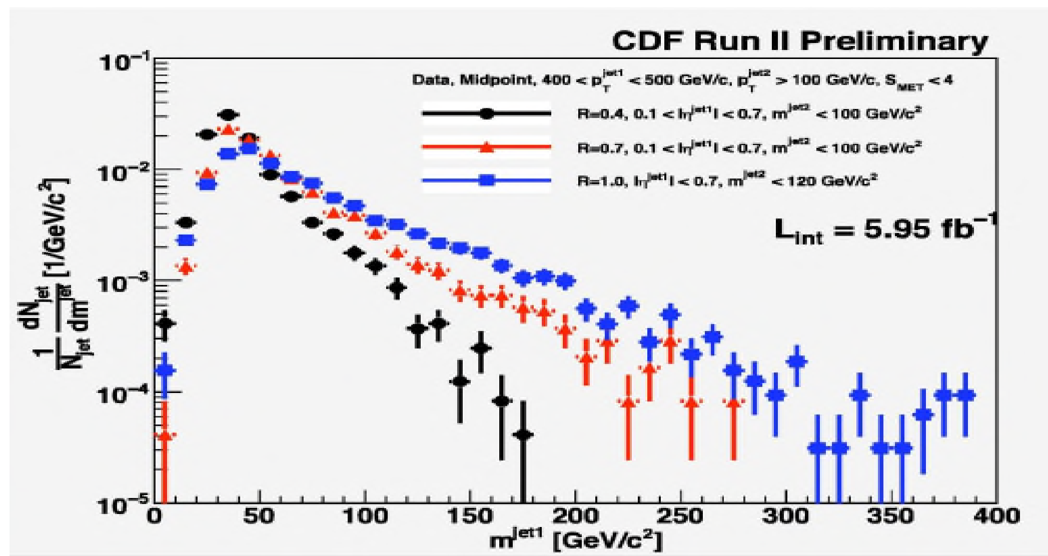
Extras

Jet Mass – CDF Data (CDF/PUB/JET/PUBLIC/10199 7/19/10)

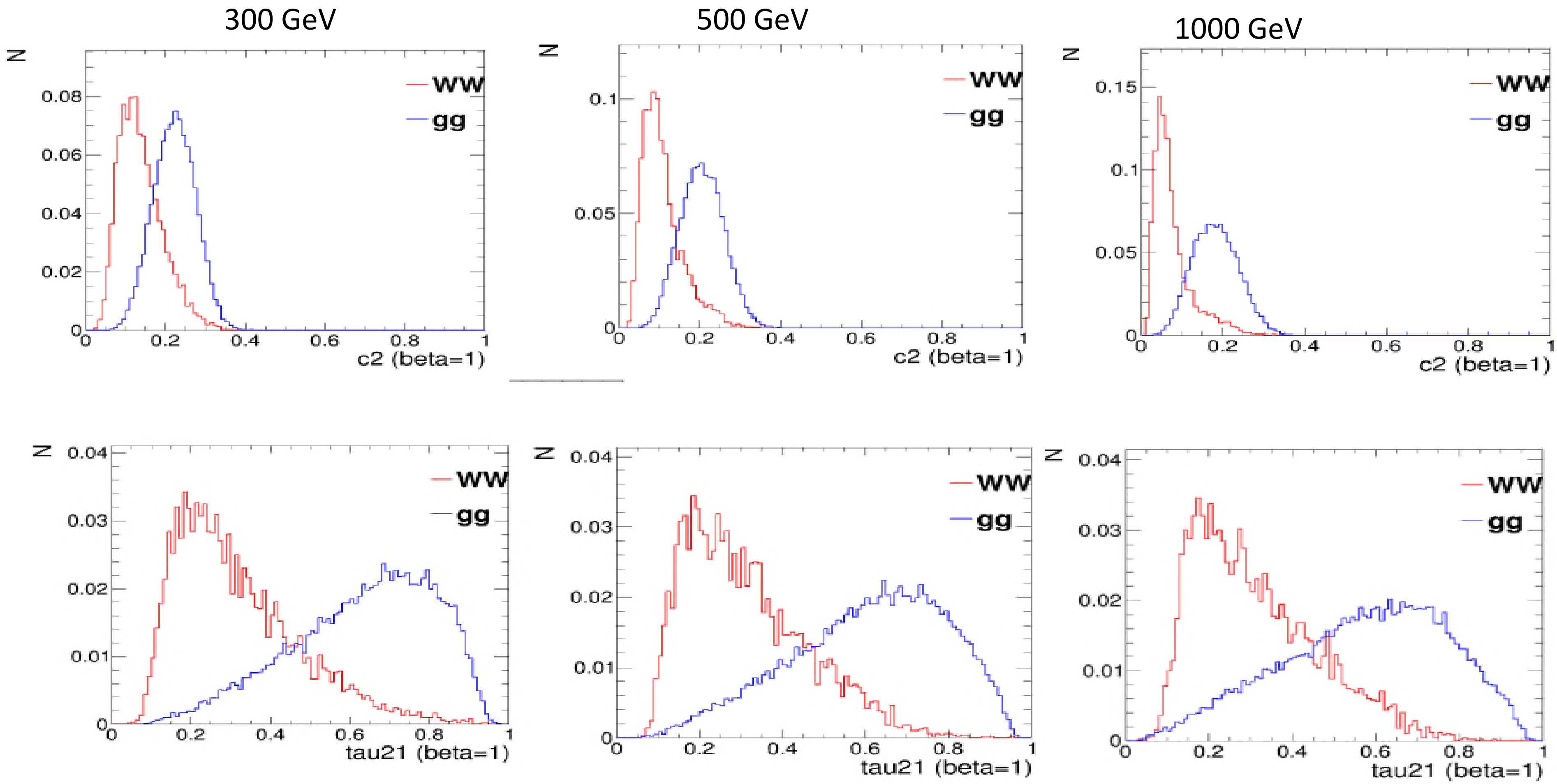


At least qualitatively the expected shape – masses slightly larger than MC – need the true hard emissions (as in matched sets)

Large mass tail grows, as expected, with jet size parameter in the algorithm -
You find what you look for!



pT Dependence, R = 0.8



Linear scale